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CHEMICAL AND PHYSICAL PROPERTIES OF LUBRICANTS AND HYDRAULIC FLUIDS

PHOENIX CHEMICAL LABORATORY, INC.
CHICAGO, ILLINOIS 60647

JUNE 1976

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AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
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This Technical Report has been reviewed and is approved.

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The method for the determination of the linear flame propagation rates of lubricants and hydraulic fluids has been studied further and has been applied to a variety of samples. A new method for the evaluation of the ignition of organic liquids by hot surfaces has been developed. Data have been obtained for a variety of different samples. The measurement of oxygen absorption rates has been used for the study of the oxidative stabilities of experimental lubricants and hydraulic

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20. Abstract Continued:

fluids both in the presence and in the absence of metal catalysts. The chemical and physical properties of various lubricants and hydraulic fluids have been studied. Special emphasis has been directed toward the investigation of properties relevant to the performance of lubricants and hydraulic fluids under conditions of thermal and oxidative stress.

FOREWORD

This report was prepared by Phoenix Chemical Laboratory, Inc., under USAF Contract No. F33615-73-C-5103. The contract was initiated under Project No. 7343. The work was administered under the direction of the Air Force Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, with Carl E. Snyder, Jr., as project engineer.

The report covers work performed between 1 April 1973 and 31 March 1976. The report was submitted by the authors in July 1976.

The authors acknowledge the special contributions of John Krawetz who conceived and initiated many of the studies herein reported. John Krawetz died on 15 January 1974 and was unable to see his work through to completion. He will be missed. Others who contributed to the experimental phases of this work are P. Klinsuttho, G. Kroma, T. Kitchlew, I. Rodriguez, A. Thakkar, P. Shukla and H. Gillespie (deceased November 1974).

The authors wish to thank Carol Wilson for her efforts in the preparation of this report.

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SECTION I

DETERMINATION OF LINEAR FLAME PROPAGATION RATES

1.1 Introduction:

A method for the determination of the linear flame propagation rates of lubricants and hydraulic fluids has previously been described and applied to a variety of sample systems (reference 1). Data obtained in the initial study indicated that the method was capable of more than adequate precision and that it was easily capable of revealing small differences in the linear flame propagation rates of samples to which it was applied. Application of the procedure to determine the linear flame propagation rates of various samples and mixtures revealed that there is reason to believe that the rate of linear flame propagation may be correlated both with performance in the gunfire test and with performance in the horizontal flame propagation and relative ignitability tests developed by the Naval Air Propulsion Center. (Table I and References 2 and 3) Other data indicated that the addition of a non-propagating fluid (ie, one for which the linear flame propagation rate is zero) to a propagating one (ie, one for which a finite linear flame propagation rate exists) may reduce the rate of propagation of the mixture by more than that which might be expected on a strictly additive basis. This discovery suggested that a strong possibility might exist for the production of significant improvements in this aspect of flammability through the use of additives.

In the present investigation effort has been directed towards the evaluation of two experimental factors: (1) vertical flame propagation as opposed to horizontal propagation as used in all previous studies. (2) effects of support diameter on propagation rates. Application of the technique to lubricants and hydraulic fluids has continued. Extensive data have been obtained for blends of a fluid of low propagation rate (MLO-73-6) with one of known high propagation rate (MIL-H-5606B). A variety of other experimental fluids has also been evaluated.

TABLE I

CORRELATION OF LINEAR FLAME PROPAGATION RATES AND RELATIVE IGNITABILITY BY NAPC METHOD

LABORATORY NUMBER	SAMPLE MARKED	LINEAR FLAME PROPAGATION RATE, cm/sec.	RELATIVE IGNITABILITY cm/sec.
2176	C	0.199	No ignition, no flame
2177	D	0.215	No ignition, no flame
2179	F	0.908	3.3
21710	G	0.297	No ignition, no flame

1.2 Experimental:

1.2.1 Apparatus and Materials:

The following apparatus and materials have been used during the course of the present investigation:

1) Apparatus for measurement of linear flame propagation rates (See Reference 1).
2) Recorder, stripchart, fast response: A zero-centered recorder with a ± 5 mv range and a one-half second full scale deflection capability has been found to be satisfactory. A chart speed of 3" per minute has been used for most studies.
3) Differential thermocouple pair, 30 gauge, with bare junctions and double fiberglass wrap insulation, ISA Type J.
4) Fume hood, draft free when ventilation system is not operative.
5) Weights, 50 gram, with attached hooks: two required.
6) Chrome plated tube or rod, 5/8" dia. x 15" long.
7) Porcelain or glass dish, approximately 125 ml. capacity.
8) Asbestos cord, 0.031" dia. and 0.055" dia.
9) Absorbent paper wipers, 15" x 8-3/8": Type 900 M Kimwipes have been found to be satisfactory.
10) Ignition source: any paper book matches or wooden kitchen matches may be used.

1.2.2 Procedure:

The following procedure has been used for the experiments described in the present report:

1.2.2.1 Tie small loops in each end of a 20" section of asbestos string. Place a few milliliters of the sample to be studied in an evaporating dish. Immerse the asbestos string in the liquid sample. Avoid immersion of the loops at the ends of the string.

1.2.2.2 While the asbestos string is immersed in the sample carefully wrap an absorbent paper wiper around a 5/8" diameter chrome plated rod. Leave one end of the rod uncovered by the wiper.

1.2.2.3 Remove the asbestos string section from the liquid sample and hook a 50 gram weight to the loop at each end. Fix the chrome plated rod with its absorbent paper wrapping in a horizontal position and hang the soaked string section with attached weights over the unwrapped section of the rod. Press down gently on the uppermost weight to cause the soaked string to pass over the bare rod, flexing gently as it moves. When the lower weight has been drawn up to the rod, reverse the process until the first weight has again been drawn up to the rod. Repeat the cycle four times to work the sample thoroughly into the string.

1.2.2.4 Transfer the string with attached weights to the covered portion of the chrome plated rod. Pass the string over the absorbent paper in the manner described in 1.2.2.3. After each complete double cycle lift the string from the paper, rotate it through 180 degrees as it is held taut in a vertical position and then replace it on a fresh area of the absorbent medium. Again pass the string over the paper in the manner described in 1.2.2.3. Repeat until four double cycles have been completed.

1.2.2.5 Place the string support and thermocouple holder in a draft free hood with the ventilation turned off. Level the apparatus with a spirit level. Place the prepared string on the string supports. The attached weights should be left in place to provide tension in the string. Adjust the differential thermocouple junctions so that they are exactly 2 mm directly above the string. Connect the differential thermocouple pair to the fast response, zero-centered strip-chart recorder.

1.2.2.6 Start the recorder chart after an appropriate warm-up period. With a match ignite the sample on the string near its support at one end of the apparatus. Permit the flame to advance along the string past each thermocouple until it extinguishes itself upon reaching the opposite string support. Stop the recorder and start the hood ventilator to exhaust the combustion products of the sample.

Note: Extreme care should be taken to avoid inhalation of the combustion products as extremely toxic substances are formed during the combustion of some synthetic materials, especially halogenated materials.

1.2.2.7 Measure the interval between the first thermal effects (Reference 1). From the measured interval, the chart speed of the recorder and the known horizontal distance between thermocouples in the test apparatus, calculate and report the horizontal linear flame propagation rate in cm/sec. If the flame does not advance during the experimental run, or, if it extinguishes itself before passing both thermocouples, record that fact. Replicate runs shall be made as required.

1.2.2.8 The vertical flame propagation rate (upward or downward propagation) may be determined by use of essentially the same procedure as described in 1.2.2.1 through 1.2.2.7. The test apparatus is turned on end and the asbestos cord affixed to a post at the top of the apparatus. One 50 gram weight is used to hold the cord taut. The sample is introduced as described above and ignited at the top or bottom of the cord depending upon whether upwards or downwards vertical propagation is desired. Data are obtained in the same manner as before.

1.2.3 Experimental Data:

1.2.3.1 Vertical Flame Propagation Studies: Linear flame progagation rate studies have been made by use of both upwards and downwards propagation. Data for the same samples are compared with horizontal propagation studies which have been run for the same samples. The results which have been obtained are shown in Tables II through V.

1.2.3.2 Effects of Support Diameter on Propagation Rate:

Horizontal linear flame propagation rate studies were conducted with two diameters of asbestos cord (cf 1.2.1.8). The data which have been obtained are shown in Tables VI through VIII.

1.2.3.3 Measurement of the Linear Flame Propagation Rate of Blends of Lubricants: The linear horizontal flame propagation rates of several blends of two experimental lubricants have been measured. The results which have been obtained are shown in Tables IX through XIV.

1.2.3.4 Measurement of the Linear Flame Propagation Rates of Lubricants and Hydraulic Fluids:

The linear horizontal flame propagation rates of nineteen samples were measured. The results which have been obtained are shown in Tables XV through XXXIII.

TABLE II

LINEAR FLAME PROPAGATION RATE
SAMPLE NUMBER MLO 71-68

Run	Horizontal Propagation Rate, cm/sec.	Vertical (Downward) Propagation Rate, cm/sec.	Vertical (Upward) Propagation Rate, cm/sec.
1	0.324	0.178	4.06
2	0.302	(note 1)	6.77
3	0.309	0.186	4.06
4	0.290	(note 2)	4.35
5	0.302	0.172	3.59
6	0.276	0.174	2.77
7	0.296	0.179 (note 3)	3.21
8	0.293	(note 1)	5.08
9	0.294	0.177 (note 3)	3.59
10	0.318	(note 2)	5.08
11		(note 1)	
12		(note 2)	
13		0.183	
14		0.200	
15		0.177 (note 3)	
16		0.192	
Average	0.300	0.182	4.24
Standard Deviation	0.014	0.009	1.17
Probable Error	0.009	0.006	0.79
Probable Error, %	3.0	3.3	18.6

Note 1: Flame self-extinguished at mid-run.
Note 2: Flame self-extinguished at first thermocouple.
Note 3: Flame self-extinguished at second thermocouple.

TABLE III

LINEAR FLAME PROPAGATION RATE
SAMPLE NUMBER MLO 73-17

Run	Horizontal Propagation Rate, cm/sec.	Vertical (Downward) Propagation Rate, cm/sec.
1	0.376	0.189
2	0.333	0.175
3	0.398	0.174
4	0.333	(note 1)
5	0.322	(note 2)
6	0.297	0.174
7	0.328	0.190
8	0.333	0.185
9	0.335	0.195
10	0.350	0.192
11		0.190
12		0.184
Average	0.340	0.185
Standard Deviation	0.028	0.008
Probable Error	0.019	0.005
Probable Error, %	5.6	2.7

Note 1: Flame self-extinguished at first thermocouple.
Note 2: Flame self-extinguished at mid-run.

TABLE IV

LINEAR FLAME PROPAGATION RATE
SAMPLE NUMBER MLO 73-51

Run	Horizontal Propagation Rate, cm/sec.	Vertical (Downward) Propagation Rate, cm/sec.
1	0.515	0.292
2	0.438	0.300
3	0.446	0.290
4	0.505	0.280
5	0.484	0.264
6	0.540	0.260
7	0.508	0.253
8	0.505	0.294
9	0.484	0.281
10	0.508	0.277
Average	0.493	0.279
Standard Deviation	0.031	0.016
Probable Error	0.021	0.011
Probable Error, %	4.3	3.9

TABLE V

LINEAR FLAME PROPAGATION RATE
MIL-H-5606B

Run	Horizontal Propagation Rate, cm/sec.	Vertical (Downward) Propagation Rate, cm/sec.
1	0.701	0.410
2	0.734	0.429
3	0.709	0.423
4	0.734	0.421
5	0.772	0.386
6	0.743	0.421
7	0.725	0.429
8	0.762	0.429
9	0.725	0.426
10	0.725	0.446
Average	0.733	0.422
Standard Deviation	0.022	0.016
Probable Error	0.015	0.011
Probable Error, %	2.0	2.6

TABLE VI

LINEAR HORIZONTAL FLAME PROPAGATION RATE
SAMPLE NUMBER MLO 73-51

Run	Linear Horizontal Flame Propagation Rate, cm/sec. Thin Asbestos Cord (0.031" diameter)	Thick Asbestos Cord (0.055" diameter)
1	0.515	0.221
2	0.438	0.226
3	0.446	0.244
4	0.505	0.229
5	0.484	0.244
6	0.540	0.224
7	0.508	0.218
8	0.505	0.256
9	0.484	0.267
10	0.508	0.238
Average	0.493	0.237
Standard Deviation	0.031	0.016
Probable Error	0.021	0.011

TABLE VII

LINEAR HORIZONTAL FLAME PROPAGATION RATE
SAMPLE NUMBER MLO 73-75

Run	Linear Horizontal Flame Propagation Rate, cm/sec. Thin Asbestos Cord (0.031" diameter)	Thick Asbestos Cord (0.055" diameter)
1	0.201	0.097
2	0.216	(note 2)
3	0.198	(note 1)
4	0.218	(note 2)
5	0.224	0.106
6	0.221	0.106
7	0.221	0.105
8	0.226	0.110
9	0.219	(note 2)
10	0.231	0.103
11		0.104
12		0.112
13		0.108
14		0.109
Average	0.218	0.106
Standard Deviation	0.010	0.004
Probable Error	0.007	0.003

Note 1: Flame self-extinguished at mid-run.
Note 2: Flame self-extinguished at first thermocouple.

TABLE VIII

LINEAR HORIZONTAL FLAME PROPAGATION RATE
MIL-H-5606B

Run	Thin Asbestos Cord (0.031" diameter)	Thick Asbestos Cord (0.055" diameter)
	Linear Horizontal Flame Propagation Rate, cm/sec.	
1	0.701	0.455
2	0.734	0.458
3	0.709	0.484
4	0.734	0.452
5	0.772	0.484
6	0.743	0.500
7	0.725	0.512
8	0.762	0.476
9	0.725	0.564
10	0.725	0.500
Average	0.733	0.489
Standard Deviation	0.022	0.034
Probable Error	0.015	0.023

TABLE IX

LINEAR FLAME PROPAGATION RATE 100% OF SAMPLE MLO-73-6

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.181
2	0.189
3	---x
4	0.169
5	0.185
6	---x
7	---x
8	0.245
9	---x
10	0.216
11	0.226
12	0.233
13	0.238
14	0.238
Average	0.212
Standard Deviation	0.026
Probable Error	0.018

---x Flame self-extinguished before completion of test run

TABLE X

LINEAR FLAME PROPAGATION RATE
97% OF SAMPLE MLO-73-6
3% OF MIL-H-5606B

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.261
2	0.236
3	0.222
4	---x
5	0.219
6	0.233
7	0.234
8	0.261
9	0.242
10	0.226
11	0.261
Average	0.240
Standard Deviation	0.016
Probable Error	0.011

---x Flame self-extinguished before completion of test run

TABLE XI

LINEAR FLAME PROPAGATION RATE
95% OF SAMPLE MLO-73-6
5% OF MIL-H-5606B

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.324
2	0.324
3	0.314
4	0.335
5	0.321
6	0.318
7	0.314
8	0.321
9	0.321
10	0.318
Average	0.321
Standard Deviation	0.006
Probable Error	0.004

TABLE XII

LINEAR FLAME PROPAGATION RATE
90% OF SAMPLE MLO-73-6
10% OF MIL-H-5606B

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.339
2	0.321
3	0.328
4	0.318
5	0.331
6	0.318
7	0.335
8	0.308
9	0.350
10	0.328
Average	0.327
Standard Deviation	0.012
Probable Error	0.008

TABLE XIII

LINEAR FLAME PROPAGATION RATE
75% OF SAMPLE MLO-73-6
25% OF MIL-H-5606B

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.398
2	0.352
3	0.367
4	0.352
5	0.365
6	0.365
7	0.388
8	0.383
9	0.367
10	0.381
Average	0.372
Standard Deviation	0.015
Probable Error	0.010

TABLE XIV

LINEAR FLAME PROPAGATION RATE
100% OF MIL-H-5606B

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.701
2	0.734
3	0.709
4	0.734
5	0.772
6	0.743
7	0.725
8	0.762
9	0.725
10	0.725
Average	0.733
Standard Deviation	0.022
Probable Error	0.015

TABLE XV

SAMPLE NUMBER MLO-73-51

LINEAR FLAME PROPAGATION RATE

Run	Flame Propagation, cm./sec.
1	0.515
2	0.438
3	0.446
4	0.505
5	0.484
6	0.540
7	0.508
8	0.505
9	0.484
10	0.508
Average	0.493
Standard Deviation	0.031
Probable Error	0.021

TABLE XVI

SAMPLE NUMBER MLO-73-62

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.521
2	0.500
3	0.465
4	0.544
5	0.521
6	0.484
7	0.500
8	0.500
9	0.508
10	0.488
Average	0.503
Standard Deviation	0.022
Probable Error	0.015

TABLE XVII

SAMPLE NUMBER MLO-73-63

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.535
2	0.575
3	0.559
4	0.559
5	0.581
6	0.592
7	0.521
8	0.575
9	0.540
10	0.484
Average	0.552
Standard Deviation	0.033
Probable Error	0.022

TABLE XVIII

SAMPLE NUMBER MLO-73-75

LINEAR FLAME PROPAGATION RATE

Run	Flame Propagation, cm./sec.
1	0.201
2	0.216
3	0.198
4	0.218
5	0.224
6	0.221
7	0.221
8	0.226
9	0.219
10	0.231
Average	0.218
Standard Deviation	0.010
Probable Error	0.007

TABLE XIX

SAMPLE NUMBER MLO-73-76

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.302
2	0.285
3	0.305
4	0.331
5	0.296
6	0.296
7	0.308
8	0.328
9	0.285
10	0.293
Average	0.303
Standard Deviation	0.016
Probable Error	0.011

TABLE XX

SAMPLE NUMBER MLO-73-93

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.321
2	0.293
3	0.308
4	0.305
5	0.321
6	0.318
7	0.272
8	0.311
9	0.308
10	0.308
Average	0.306
Standard Deviation	0.014
Probable Error	0.010

TABLE XXI

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-3

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.343
2	0.356
3	0.332
4	0.320
5	0.328
6	0.317
7	0.318
8	0.320
9	0.320
10	0.338
Average	0.329
Standard Deviation	0.013
Probable Error	0.009

TABLE XXII

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-4

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.302
2	0.331
3	0.331
4	0.322
5	0.322
6	0.317
7	0.321
8	0.318
9	0.324
10	0.309
Average	0.320
Standard Deviation	0.009
Probable Error	0.006

TABLE XXIII

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-5

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.335
2	0.343
3	0.338
4	0.345
5	0.322
6	0.336
7	0.332
8	0.334
9	0.335
10	0.344
Average	0.336
Standard Deviation	0.007
Probable Error	0.005

TABLE XXIV

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-6

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.344
2	0.324
3	0.341
4	0.342
5	0.347
6	0.331
7	0.340
8	0.327
9	0.328
10	0.328
Average	0.335
Standard Deviation	0.008
Probable Error	0.006

TABLE XXV

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-7

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.335
2	0.324
3	0.342
4	0.336
5	0.350
6	0.321
7	0.320
8	0.325
9	0.326
10	0.330
Average	0.329
Standard Deviation	0.010
Probable Error	0.006

TABLE XXVI

LINEAR FLAME PROPAGATION RATE
SAMPLE MLO-74-8

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.296
2	0.295
3	0.291
4	0.311
5	0.287
6	0.300
7	0.287
8	0.308
9	0.297
10	0.293
Average	0.296
Standard Deviation	0.008
Probable Error	0.005

TABLE XXVII

SAMPLE NUMBER MLO-74-19

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.282
2	0.288
3	0.300
4	0.272
5	0.296
6	0.282
7	0.293
8	0.292
9	0.277
10	0.281
Average	0.286
Standard Deviation	0.009
Probable Error	0.006

TABLE XXVIII

SAMPLE NUMBER MLO-74-20

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.303
2	0.318
3	0.308
4	0.331
5	0.309
6	0.300
7	0.303
8	0.299
9	0.335
10	0.284
Average	0.309
Standard Deviation	0.015
Probable Error	0.010

TABLE XXIX

SAMPLE NUMBER MLO-74-41

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.282
2	0.290
3	0.290
4	0.290
5	0.308
6	0.297
7	0.330
8	0.299
9	0.294
10	0.326
Average	0.301
Standard Deviation	0.016
Probable Error	0.011

TABLE XXX

SAMPLE NUMBER MLO-74-42

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.313
2	0.333
3	0.314
4	0.319
5	0.328
6	0.308
7	0.316
8	0.328
9	0.311
10	0.322
Average	0.319
Standard Deviation	0.008
Probable Error	0.006

TABLE XXXI

SAMPLE NUMBER MLO-74-53

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.417
2	0.391
3	0.415
4	0.412
5	0.429
6	0.426
7	0.409
8	0.404
9	0.412
10	0.406
Average	0.412
Standard Deviation	0.011
Probable Error	0.007

TABLE XXXII

SAMPLE NUMBER MLO-74-54

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.254
2	0.244
3	0.236
4	0.265
5	0.258
6	0.234
7	0.258
8	0.280
9	0.318
10	0.308
Average	0.266
Standard Deviation	0.029
Probable Error	0.019

TABLE XXXIII

SAMPLE NUMBER MLO-74-55

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.331
2	0.314
3	0.318
4	0.311
5	0.335
6	0.318
7	0.308
8	0.321
9	0.290
10	0.314
Average	0.316
Standard Deviation	0.012
Probable Error	0.008

1.3 Conclusions

On the basis of the data which have been obtained it is possible to reach the following conclusions.

1.3.1 Vertical Flame Propagation Studies:

1.3.1.1 Vertical upward flame propagation results in rates of propagation which are approximately 14 times faster than those for horizontal propagation. Vertical downward flame propagation is approximately 60 per cent as fast as horizontal propagation.

1.3.1.2 The standard deviation and probable error for measurements of upward propagation of flame are many times greater than those for measurements of horizontal propagation. Thus, the corresponding probable percentage errors for upward and horizontal propagation rate measurements are 18.6 and 3.0 per cent in the case studied. The standard deviation and probable error for measurements of downward propagation are slightly smaller than for the horizontal; however, the percentage errors are generally comparable. There appears to be no distinct statistical advantage which favors the measurement of downward propagation flames over horizontal ones. The measurement of the rates of propagation of flames which move vertically upward is much less precise. This appears to be due to the heating of the sample by the flame as it proceeds progressively upward into regions of fresh sample. The same effect is minimized in the case of downward and horizontally propagating flames.

1.3.1.3 There appears to be a distinct disadvantage in the use of downward motion in the measurement of propagation rates. Because the rates tend to be very slow (<u>cf</u> Tables II and III) self-extinction of flame may occur quite often. Similar difficulties were not encountered when the same samples were studied under conditions of horizontal propagation. There are, of course, some samples which propagate so slowly, even in the horizontal direction, that self-extinction or non-propagation will occur.

1.3.1.4 In summary it appears that while some meaningful data might be obtained by comparative studies made in the horizontal or either vertical direction, the horizontal mode offers the best advantage in providing for the precise measurement of rates that are fast enough to propagate well, but which are not too fast to permit precise measurements nor too slow to permit continuous propagation. For these reasons all further studies have been made in the horizontal mode.

1.3.2 Effects of Support Diameter on Propagation Rate.

1.3.2.1 Propagation rates are much lower on 0.055" diameter cord than on the 0.031" diameter material.

1.3.2.2 Samples which tend to self-extinguish have in some cases been found to burn more cleanly on the larger diameter cord.

1.3.2.3 Although the skewing of data towards lower propagation rates cases the differentiation between samples to be less distinct for measurements made with the larger cord, such measurements may have utility for the comparison of samples which propagate not at all or only with difficulty on the small diameter cord.

1.3.2.4 For general utility the 0.031" diameter cord appears to be superior to the 0.055" diameter material. All future measurements, unless otherwise specified will be made with 0.031" diameter cord.

1.3.3 Linear Flame Propagation Rates of Blends:

1.3.3.1 The addition of small amounts of MIL-H-5606B (a fluid of high propagation rate) to a base of MLO-73-6 (a fluid of relatively low propagation rate) produces mixtures the propagation rates of which are generally much larger than would be expected were the propagation rate a strictly additive property. The greatest increases occur for the 5 and 10 per cent mixtures.

1.3.3.2 The data suggest that even a relatively small amount of a fluid such as MIL-H-5606B may have a seriously detrimental effect on the flammability properties of a fluid such as MLO-73-6.

1.3.3.3 Additional studies should be performed to determine whether the above-mentioned effect is general. The reverse effect, namely, the improvement of flammability properties by the addition of a small amount of a non-propagating fluid has also been observed (Reference 1) and should be studied further.

SECTION II

IGNITION OF LUBRICANTS AND HYDRAULIC FLUIDS ON HOT SURFACES

2.1 Introduction:

A multiplicity of test procedures is available for the evaluation of the fire hazards involved in the use of fuels, lubricants, hydraulic fluids and related materials of both petroleum and synthetic origin. The oldest and most widely used of these are the ASTM standard methods of test for flash point, fire point and autoignition temperature. Standard tests of more recent vintage include methods for the determination of mist spray flammability and reaction threshold temperature. Measurement of linear flame propagation rates has also been shown to be relevant to field performance under conditions of stress such as those imposed by the gun-fire test (cf Section 1 and Reference 1). Wick-type ignition tests in which a pipe cleaner saturated with an hydraulic fluid is oscillated through a flame have also been proposed.

None of the aforementioned procedures has been found to be completely satisfactory for the simulation of ignition reactions induced by the contact of lubricants and hydraulic fluids with hot surfaces. Under such conditions ignition is influenced by volatilization rate to a much greater extent than in any of the above standard methods used for the evaluation of flammability. Thus, when a hot surface is the only source of ignition, extremely low-flashing fuels such as gasoline may be ignited only with difficulty. The reason for this behavior apparently is that the high volatilization rate of the fuel on the hot surface both cools the surface locally and causes the rapid loss of the flammable vapors from the heated area before they can be raised to their autoignition temperature. A similar phenomenon is observed with MIL-H-5606 type hydraulic fluids which have relatively low flash and autoignition tmeperatures, both which perform moderately well when evaluated by various hot-manifold ignition tests.

A number of tests have been proposed for the estimation of the relative ignitability of high pressure oil mists and sprays by hot surfaces. These include, but are not limited to, such tests as high temperature, high pressure spray ignition tests in which a sample is sprayed under standardized conditions onto hot surfaces which simulate a high temperature exhaust manifold. Examples of such tests which are currently in use are the Factory Mutual Hot-Channel Test (Reference 4) and the hot manifold ignition test described in the Federal Test Method Standard 791b, Method 6053 (Reference 5). While these procedures have achieved a degree of acceptance, they have a number of distinct disadvantages. Perhaps the chief among these involve environmental and occupational safety considerations. The relatively large scale hot channel and hot manifold tests are capable of producing copious amounts of very unpleasant and potentially toxic fumes which can neither safely be released in work areas (cf applicable regulation of the Occupational Safety and Health Administration-OSHA) nor be discharged to the atmosphere without potential violation of local, state and Federal environmental codes. Operator respiratory safety can be insured by the use of appropriate protective devices (ie self-contained breathing apparatus). Nevertheless, in the conduct of relatively large scale tests, the possible existence of abnormally violent reactions much be considered as a potential source of hazard to test operators.

Considerations such as the above have lead to the design and construction of a miniaturized apparatus for the evaluation of the ignition of lubricants and hydraulic fluids on a hot surface. In the following sections the apparatus and test procedure are described. Data which have been obtained for a variety of systems are reported.

2.2 Experimental:

2.2.1 Apparatus and Materials

The following apparatus and materials have been used during the course of the present investigation:

2.2.1.1 Apparatus for measurement of ignition of lubricants and hydraulic fluids on hot surfaces. See Figure 1 for schematic representation of mechanical and electrical systems.

2.2.1.2 Heater, Precision Scientic Co. Type RH, 550 watt, catalog number 61560.

2.2.1.3 Temperature controller: Barber Colman Model 293 Capacitrol or equivalent.

2.2.1.4 Temperature Read-Out device. Leeds and Northup Model 913 Numatron or equivalent.

2.2.1.5 Stainless steel planchet, 26 gauge, 50 mm diameter x 12.7 mm deep.

2.2.1.6 Pyrex Chimney, 70 mm O.D. x 230 mm high.

2.2.1.7 Planchet holder, transite, 127 x 127 x 12.7 mm thick with 54 mm diameter centrally located round hole to hold planchet. See Figure 2.

2.2.1.8 Asbestos cord, 0.031" diameter.

2.2.1.9 Iron-Constantan thermocouple wire precision grade, 24 gauge, silicone-impregnated fiber-glass insulation and wrap.

2.2.1.10 Teflon tipped 0.5 ml hypodermic syringe with 18" 26 gauge needle. Hamilton No. 750.

2.2.2 Procedure:

2.2.2.1 Weld a control thermocouple to the bottom of a clean stainless steel planchet and weld a read-out thermocouple to the inner surface (See Figure 1).

2.2.2.2 Wrap the outer edge of the planchet with 0.031" diameter asbestos cord and insert planchet into planchet-holder and mount assembly in heater. Mount chimney over planchet.

2.2.2.3 Connect thermocouples to control and read-out devices.

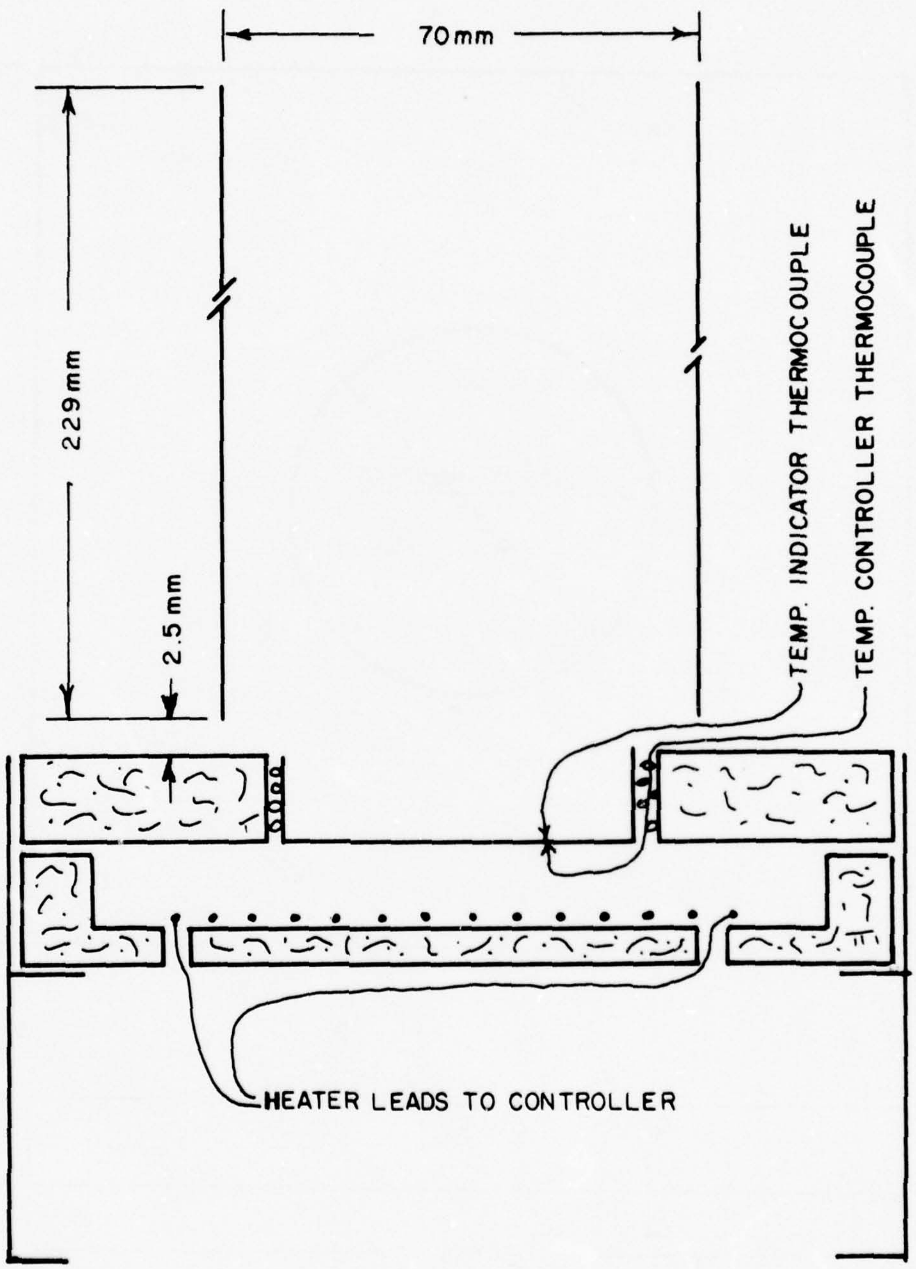

FIGURE 1. APPARATUS FOR THE MEASUREMENT OF IGNITION OF LUBRICANTS AND HYDRAULIC FLUIDS IN HOT SURFACES.

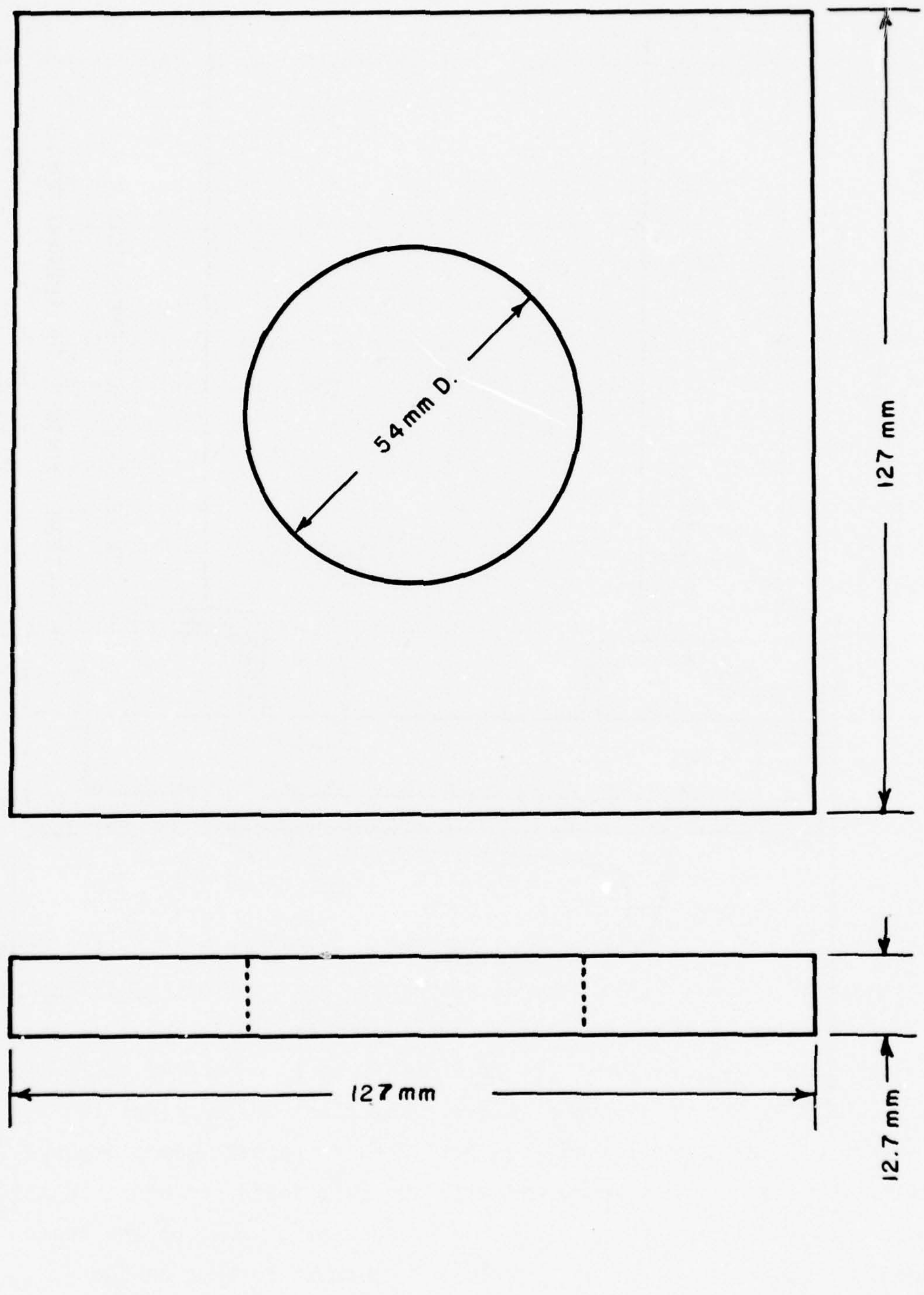

FIGURE 2. PLANCHET SUPPORT

2.2.2.4 Turn on apparatus, bring to equilibrium at the desired test temperature and spray 0.1 ml of the sample on the hot planchet surface with a hypodermic syringe.

2.2.2.5 Observe any reactions which occur. Record whether the sample did or did not ignite and whether sparks occurred, deposits formed, unusual smoke or fumes occurred, etc.

2.2.2.6 If ignition did not occur in 2.2.2.4, proceed to make measurements at successively higher temperatures until ignition is observed. Make sufficient measurements to define the ignition temperature to the nearest 10 deg. F. If ignition occurred at the first temperature, proceed to make measurements at successively lower temperatures until the temperature for onset of ignition is defined to the nearest 10 deg. F.

2.2.2.7 Repeat 2.2.2.4 through 2.2.2.6 for 0.05 and 0.2 ml sample sizes.

2.2.2.8 Report the lowest ignition temperature found as the hot surface ignition temperature of the sample.

2.2.3 Experimental Data:

The experimental data obtained during the course of the present investigation are summarized in Tables XXXIV through XLVIII.

2.3 Conclusions:

The hot surface ignition temperatures of the samples studied are reported in Table XLIX. The data indicate that the method is capable of discriminating between the hot surface ignition temperatures of samples of widely varying properties. It is interesting to note that MIL-H-5606B fluid, which is known to have relatively low flash and autoignition temperatures, has a moderately high hot surface ignition temperature. Similar results have been observed with the full scale hot-manifold and hot channel ignition tests. Since the identities of most of the other samples are unknown, it is not possible to comment further on the significance of the test results.

TABLE XXXIV

SAMPLE NUMBER MIL-H-5606B

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	970
0.1	970
0.2	980

TABLE XXXV

SAMPLE NUMBER MIL-H-8446

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	840
0.1	820
0.2	830

Heavy deposits formed.

TABLE XXXVI

SAMPLE NUMBER MIL-H-27601

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	950
0.1	940
0.2	940

TABLE XXXVII

SAMPLE NUMBER MIL-L-7808G

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	1040
0.1	1070
0.2	1090

TABLE XXXVIII

SAMPLE NUMBER MLO-68-1

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	810
0.1	790
0.2	810

TABLE XXXIX

SAMPLE NUMBER MLO-69-35

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	1090
0.1	1050
0.2	1040

TABLE XL

SAMPLE NUMBER MLO-69-51

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	930
0.1	920
0.2	920

TABLE XLI

SAMPLE NUMBER MLO-71-18

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	1080
0.1	1070
0.2	1070

TABLE XLII

SAMPLE NUMBER MLO-71-37

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	Over 1200
0.1	Over 1200
0.2	1200

Using 0.2 ml. samples one out of four runs ignited.

TABLE XLIII

SAMPLE NUMBER MLO-71-45

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	830
0.1	840
0.2	850

TABLE XLIV

SAMPLE NUMBER MLO-73-6

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	850
0.1	770
0.2	770

TABLE XLV

SAMPLE NUMBER MLO-73-45

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	880
0.1	880
0.2	850

TABLE XLVI

SAMPLE NUMBER MLO-73-51

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	1010
0.1	980
0.2	990

TABLE XLVII

SAMPLE NUMBER MLO-73-64

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	920
0.1	900
0.2	910

TABLE XLVIII

SAMPLE NUMBER MLO-73-75

PHOENIX CHEMICAL LABORATORY MINATURE HOT-MANIFOLD IGNITION TEST

Sample Volume, ml.	Ignition Temperature, Deg. F.
0.05	760
0.1	750
0.2	760

TABLE XLIX

HOT SURFACE IGNITION TEMPERATURES

Sample	Hot Surface Ignition Temperatures, deg. F
MIL-H-5606B	970
MIL-H-8446	820
MIL-H-27601	940
MIL-L-78-8G	1,040
MLO-68-1	790
MLO-69-35	1,040
MLO-69-51	920
MLO-71-18	1,070
MLO-71-37	1,200
MLO-71-45	830
MLO-73-6	770
MLO-73-45	850
MLO-73-51	980
MLO-73-64	900
MLO-73-75	750

SECTION III

ABSORPTION OF OXYGEN BY LUBRICANTS AND HYDRAULIC FLUIDS AT ELEVATED TEMPERATURES

3.1 Introduction:

A concern for the measurement and evaluation of the effects of the oxidative interaction of lubricants with their environment is as old as the science of lubrication technology itself. A great variety of standardized tests has been developed over the years in an attempt to simulate in the laboratory the conditions of oxidation to which lubricants are exposed during the course of their operative life. These have been used for the evaluation of finished oils, base stocks, additive packages and the catalytic effects of various elements, compounds and metal alloys. In general the test procedures may be categorized into two groups. In the first group oxidation is measured by virtue of changes in the properties of the sample lubricant subjected to oxidative stress. Thus in that case measurements of changes in acidity, viscosity, sediment formation, infrared absorption, additive depletion, color, corrosibility or dissolved metal content might be used as an index of the state of sample degradation produced by oxidative stress.

Examples of oxidation tests of the first type may be found in Federal Test Method Standard 791b, Method 5307, Corrosiveness and Oxidation-Stability of Aircraft Turbine Engine Lubricants and Method 5308.6 Corrosiveness and Oxidation Stability of Light Oils. Other related standard tests of the same general type include Institute of Petroleum Standard IP 280, Oxidation Stability of Inhibited Mineral Turbine Oils, American Society for Testing and Materials Standards, ASTM D 2893, Standard Method of Test for the Oxidation Characteristics of Extreme Pressure Oils, ASTM D 943, Standard Method of Test for the Oxidation Characteristics of Inhibited Steam Turbine Oils, ASTM D 1313, Standard Method of Test For Sludge Formation by High Pressure Oxidation Bomb, and ASTM D 873, Standard Method of Test For Oxidation Stability of Aviation Fuels (Potential Residue Method). Industrial standards such as the International Harvestor BT-10 oxidation test have achieved a wide degree of acceptance. The aforementioned list contains representative members of the first class of oxidation tests. It could be multiplied many times over in length if any

attempt to compile a comprehensive list of all tests used or proposed for the intended purpose were made.

A second widely applied class of oxidation tests exists in which oxygen absorption by the sample is measured directly as an index of the chemical strain produced by oxidative stress. Examples of this category are as follows: American Society for Testing and Materials tests ASTM D 2272, Standard Method of Test of Continuity of Steam-Turbine Oil Oxidation Stability by Rotating Bomb, ASTM D 1402, Standard Method of Test for the Effect of Copper on Oxidation Rate of Grease, ASTM D 525, Oxidation Stability of Gasoline (Induction Period Method) and D 942, Standard Method of Test for the Oxidation Stability of Lubricating Greases by the Oxygen Bomb Method. In all of the above group of tests oxygen in contact with the sample at elevated pressure and temperature is consumed by reaction with the sample and the amount of such consumption determined by measurement of a decrease in oxygen pressure. With the exception of the rotating bomb method, each of the tests involves static oxygen under pressure in contact with an essentially immobile sample interface. The contact surface to sample volume ratio is at a minimum. Because of this and because reaction products accumulate at the surface, measured induction periods are increased and reactions tend to be shut off by virtue of a blanket of reaction products between the sample and the source of oxygen.

For these reasons it was decided to develop an oxygen absorption test in which the gas would be in continuous dynamic contact with the sample. A further requirement of the new procedure would be that it permit the direct measurement of moles of oxygen consumed by the sample during the course of exposure so that rate data might be developed. During the present reporting period such a procedure has been developed and applied to several diverse sample systems.

3.2 Experimental

3.2.1 Apparatus and Materials

The following apparatus and materials have been used during the course of the present investigation.

3.2.1.1 The apparatus used for the measurement of the absorption of oxygen at elevated temperatures by lubricants and hydraulic fluids is shown schematically in Figure 3. A detail of the reaction tube and condenser system is shown in Figure 4.

3.2.1.2 Burrell gas buret, compensator tube and pressure equalization manometer. Burrell Technical Supply Co., Pittsburgh, PA.

3.2.1.3 Thermostatted air bath, Hevi-Duty Electric Co. crucible furnace, Type 86 with Barber Colman Temperature Controller, Amphitrol Model 152

3.2.1.4 Vacuum gauge, 0-30" vacuum

3.2.1.5 Gas pump. Dyne-Vac, Model 7064 or equivalent.

3.2.1.6 Flowmeter, Brooks Rotometer R-2-15-D.

3.2.1.7 Ascarite

3.2.1.8 Anhydrone

3.2.1.9 Molecular Sieve

3.2.1.10 Vacuum Pump

3.2.2 Procedure

The following procedure has been used for the experiments described in the present report:

3.2.2.1 Insert an empty reaction tube in the thermostatted air bath, turn on the bath and allow it to come to equilibrium at the selected test temperature.

3.2.2.2 If a metal disc catalyst is to be used polish all surfaces, rinse with clean precipitation naphtha, air dry and weigh.

3.2.2.3 Weigh a clean reaction tube (without O-ring seal), add 10 ml of sample and reweigh. Place catalyst in the bottom of the tube if required. Assemble apparatus by inserting o-ring and attaching condenser and oxygen delivery tube to reaction tube in such a manner that the oxygen delivery tube passes through the center hole of the catalyst disc. Clamp all joints and attach assembly to apparatus by making appropriate tubing connections. Turn on condenser coolant and pack cold trap with ice.

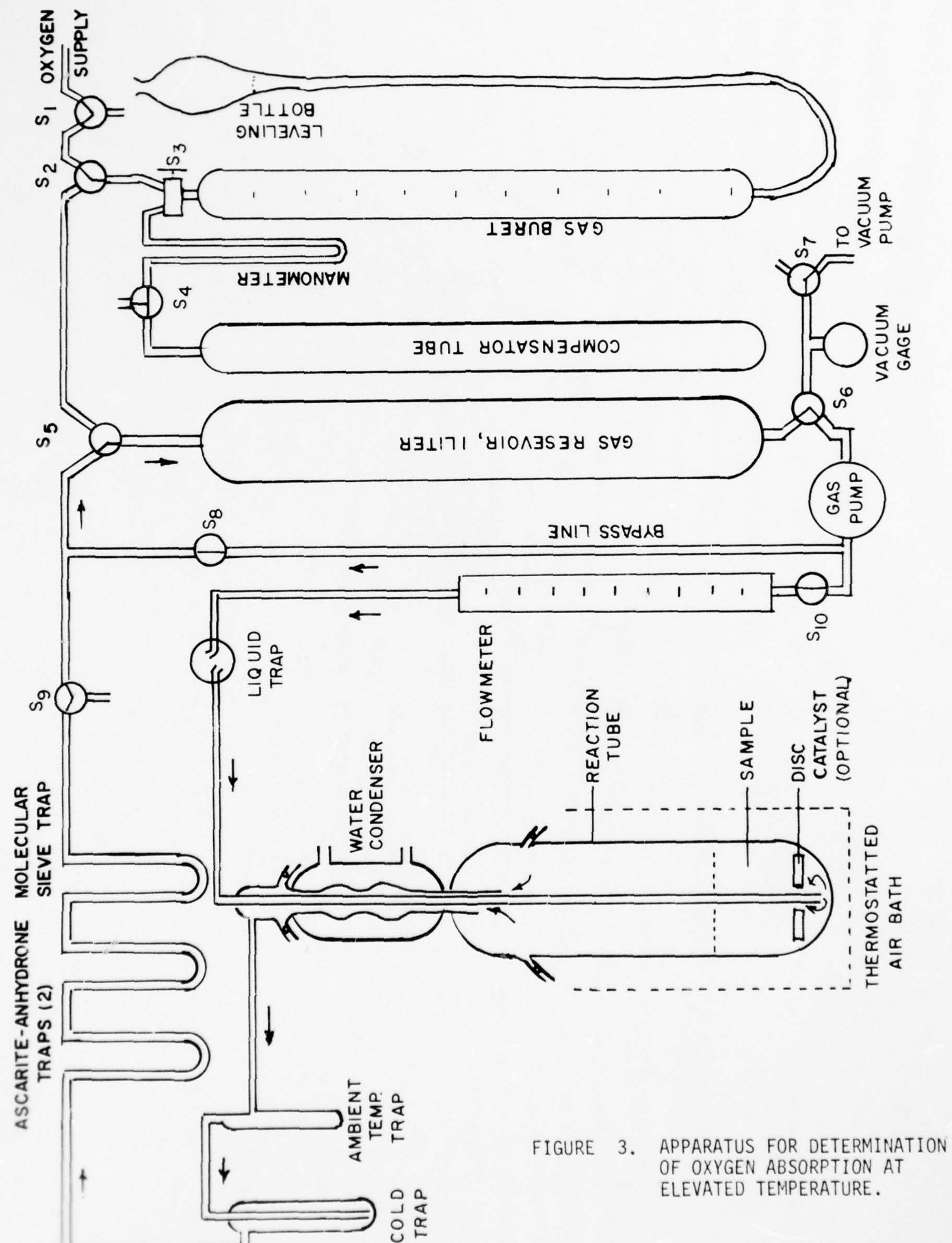

FIGURE 3. APPARATUS FOR DETERMINATION OF OXYGEN ABSORPTION AT ELEVATED TEMPERATURE.

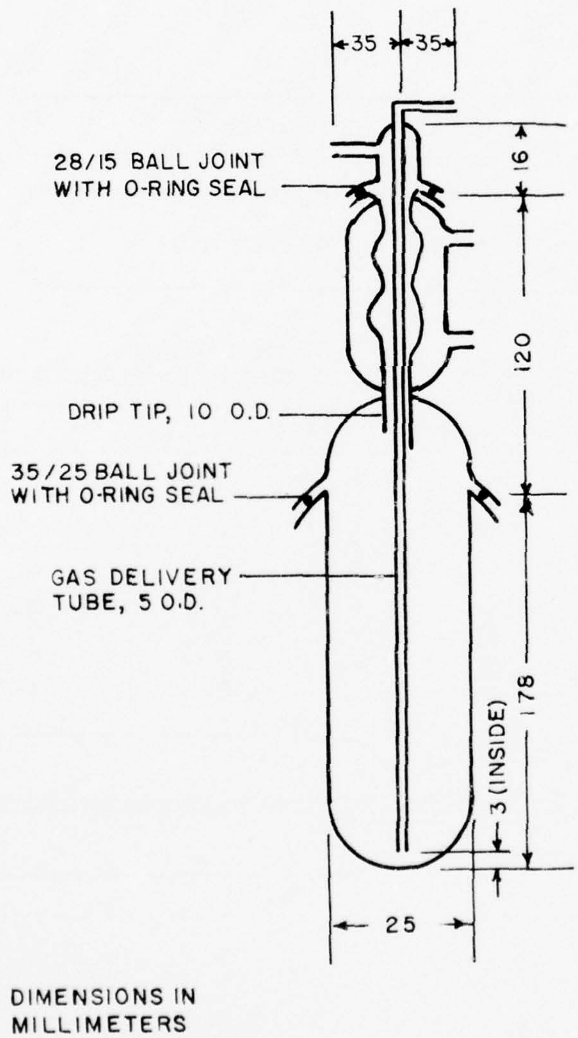

FIGURE 4. REACTION TUBE AND CONDENSER SYSTEM.

3.2.2.4 Purge the oxygen supply lines to the atmosphere through S-1. Position S-2, S-5, S-6 and S-7 so that the gas reservoir and lines may be evacuated by the vacuum pump through S-7. Close S-7 and bleed oxygen into the system through S-1 until the vacuum gauge indicates that the reservoir and lines are filled to a pressure of one atmosphere. Repeat the evacuation and filling procedure two times. Connect vacuum pump to atmosphere through S-7 and turn off pump.

3.2.2.5 Position S-1, S-2, S-5 and S-9 so that the connecting lines may be flushed with oxygen through S-1 and vented to the atmosphere through S-9.

3.2.2.6 Position S-1, S-2, S-5, S-6, S-8 and S-9 so that the bypass line may be flushed with oxygen through S-1 and vented to the atmosphere through S-9.

3.2.2.7 Close S-8, open S-10 and adjust S-9 so that the flowmeter, pump, reaction tube and all traps are flushed with oxygen and vented to the atmosphere.

3.2.2.8 Discharge the contents of the gas buret to the atmosphere through S-3, S-2 and S-1. Manipulate S-1 and the leveling bulb to fill the buret half-full of oxygen at a pressure slightly greater than one atmosphere.

3.2.2.9 Vent buret through S-1 until pressure is equal to atmospheric Vent compensator tube and manometer through S-4 in the same manner. Vent reservoir, reaction tube, traps and connecting tubes through S-9 and S-7 until they are also at ambient pressure.

3.2.2.10 Close S-4 and turn S-3 to connect buret to manometer. Manometer arms should indicate equal pressure. If they do not, repeat 3.2.2.9. Measure and record ambient barometric pressure, volume of gas in buret and temperature of buret jacket.

3.2.2.11 Connect traps and reservoir by means of S-9 and S-5. Connect gas pump and reservoir by means of S-6. Open S-8 and S-10.

3.2.2.12 Confirm that S-5, S-6, S-8, S-9 and S-10 are set for closed system gas circulation and that coolant is passing through the condenser. Insert the reaction tube into the thermostatted bath which has been equilibrated with a dummy cell at the test temperature. Remove the dummy cell at the same time. Start test timer and gas circulating pump. Set the flow rate in the system to the desired level by regulation of S-8.

3.2.2.13 At predetermined intervals measure the gas volume change of the system in the following manner: turn off the gas circulating pump, turn S-2, S-3 and S-5 to join reservoir to buret and equalize mercury levels in buret and leveling bulb. Turn S-3 to manometer and note imbalance, if any. If there is an imbalance turn S-3 to reservoir and adjust leveling bulb in a manner such as to correct the imbalance. Turn S-3 to manometer and recheck pressure. Repeat last two steps as required to bring manometer into balance. Immediately turn S-5 to circulatory mode and restart gas circulation pump. Record new buret volume and temperature.

3.2.2.14 Except for very reactive samples the first readings will show an increase in system volume due to the heating of the gas in the reaction cell. As a result, it may be necessary to reduce the volume of oxygen in the buret. If that situation occurs, record the buret reading and vent a portion of the buret contents to the atmosphere through S-3, S-2 and S-1. Rebalance the manometer between the buret (See 3.2.2.13) and compensator and record the new buret reading for use in the calculation of successive volume changes. Similarly, if large oxygen absorption occurs at any time, additional gas can be added to the buret through S-1, S-2 and S-3.

3.2.2.15 At the end of the test period turn the circulating pump off and measure the final gas volume change. Seal the reservoir by closing S-5 and S-6. Disconnect the two liquid traps. Remove the reaction tube from the heat zone and allow to cool to room temperature while water continues to circulate in condenser. Turn off air bath.

3.2.2.16 Remove cold trap and allow to come to room temperature. Weigh each trap and contents. Remove contents of each trap, rinse trap with appropriate solvent, dry and reweigh to determine amount of condensed volatiles. Analyze trap contents for acidity, viscosity and infrared spectra as required.

3.2.2.17 Turn off condenser water and open reaction tube. Weigh tube and contents, remove oxidized sample, rinse tube and reweigh. Retain sample for analysis of viscosity, acidity and infrared spectrum. Wash, dry and reweigh catalyst. Record weight change and appearance. Record weight and description of any deposits remaining in reaction tube.

3.2.2.18 Flush reservoir atmosphere through titration solvent (cf ASTM D 664), and titrate with acid or base as required to determine acidity or basicity of any gaseous reaction products not absorbed on ascarite.

3.2.2.19 From the individual volume changes and cumulative volume changes, calculate the oxygen absorption (millimoles/gram) and rate of oxygen absorption (micromoles/gram/minute) of the sample. Report changes in viscosity and acidity of sample,and amount, viscosity and acidity of overhead condensates. Note the existence of any gaseous acidity.

3.2.2.20 Empty and repack ascarite/anhydrone and molecular sieve traps at the end of each experimental run or short series of runs as required.

3.2.3 Experimental Data

The experimental data obtained during the present reporting period are summarized in Tables L through LXXIV and Figures 5 through 50.

TABLE L

MLO-69-35 OXYGEN ABSORPTION
AT 450 DEG. F, 215 ml/min GAS FLOW RATE

Time, minutes (cumulative)	Total Oxygen Absorption millimols/gram						
	Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0	0.000	0.000	0.000	0.000	0.000	0	0
15	0.007	0.107	0.034	0.040	0.047	0.31	0.02
20	-	-	0.20	0.22	0.21	0.00	0.00
25	-	-	0.34	0.37	0.36	0.31	0.02
30	0.30	0.47	0.54	0.51	0.46	0.10	0.07
45	0.68	0.76	0.86	0.89	0.80	0.09	0.06
60	0.96	1.07	1.17	1.17	1.09	0.09	0.06
75	1.24	1.34	1.45	1.51	1.38	0.11	0.08
90	1.52	1.59	1.74	1.77	1.66	0.11	0.08
105	1.74	1.85	2.01	1.99	1.90	0.12	0.08
120	1.98	2.08	2.23	2.22	2.13	0.11	0.08
135	-	2.33	2.38	2.46	2.39	0.05	0.04
145	2.30	-	-	-	2.30	-	-
150	-	2.55	2.55	2.66	2.59	0.05	0.04
155	2.51	-	-	-	2.51	-	-
165	-	2.75	2.82	2.81	2.79	0.03	0.02
180	2.80	2.90	3.03	3.00	2.93	0.10	0.07
195	3.02	3.05	3.18	3.18	3.11	0.08	0.05
210	3.21	3.21	3.34	3.33	3.27	0.06	0.04
225	3.39	3.35	3.52	3.49	3.44	0.07	0.05
240	3.54	3.50	3.69	3.65	3.60	0.08	0.06

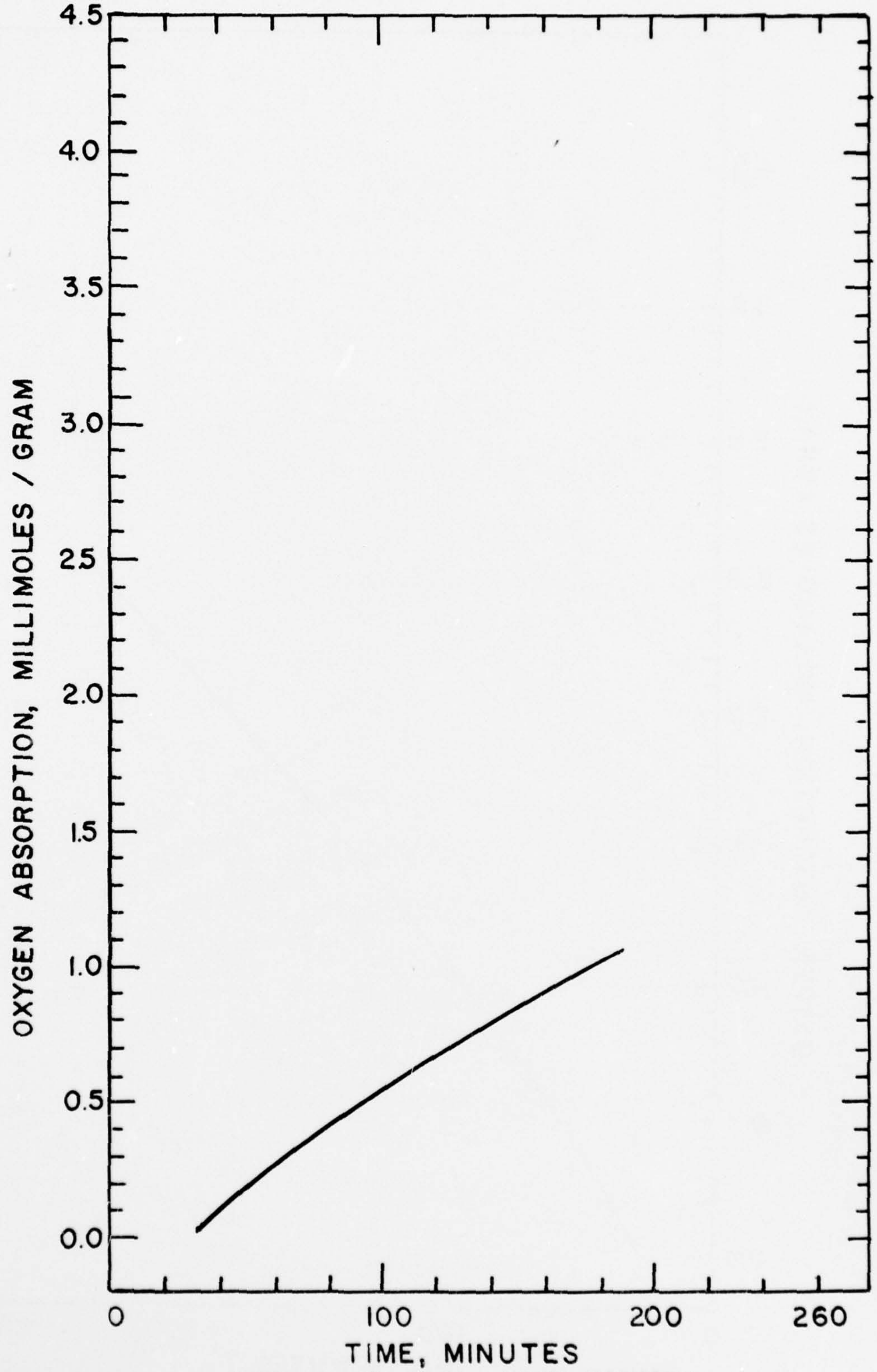

FIGURE 5. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 48 ml/min gas flow rate

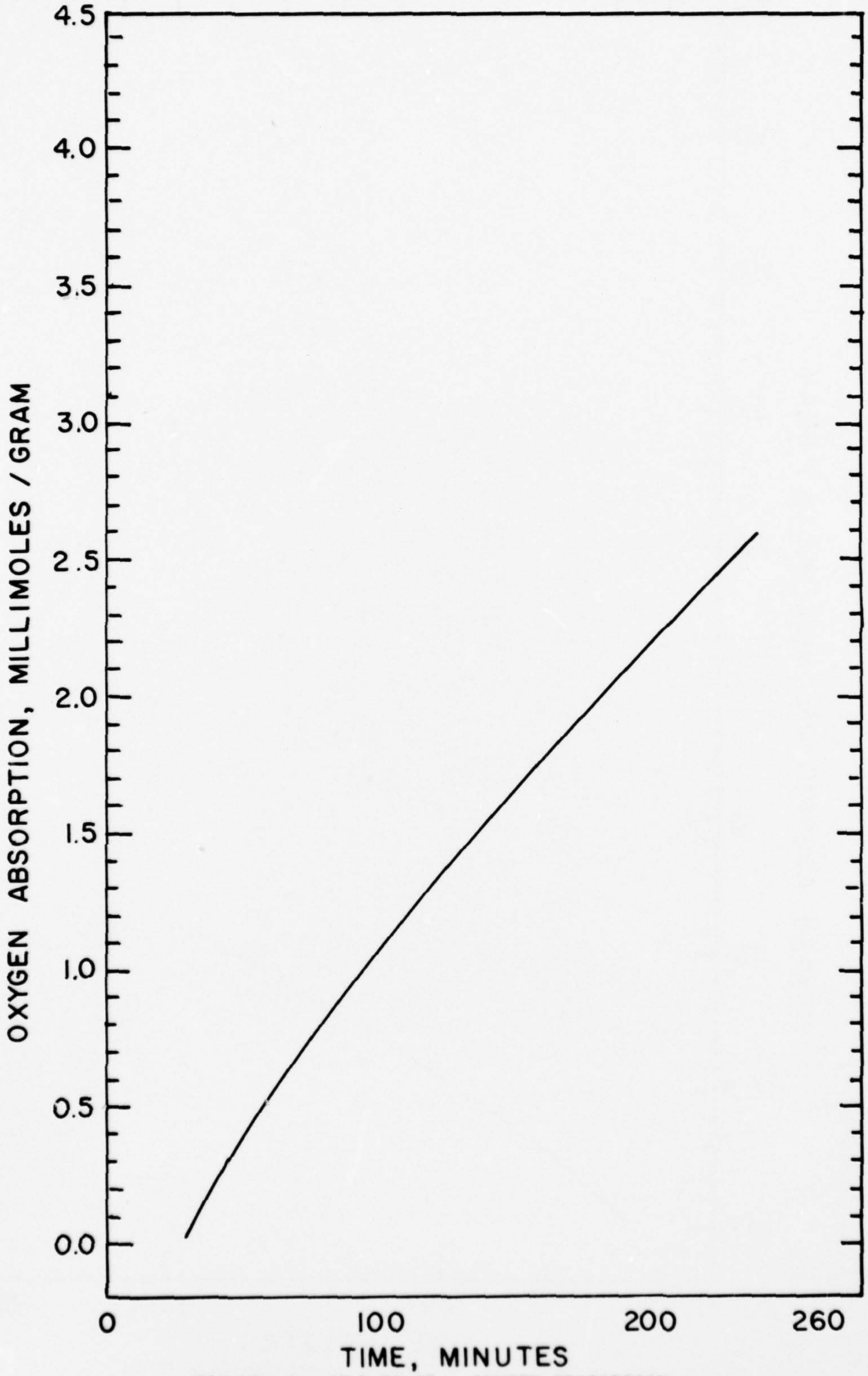

FIGURE 6. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 120 ml/min gas flow rate

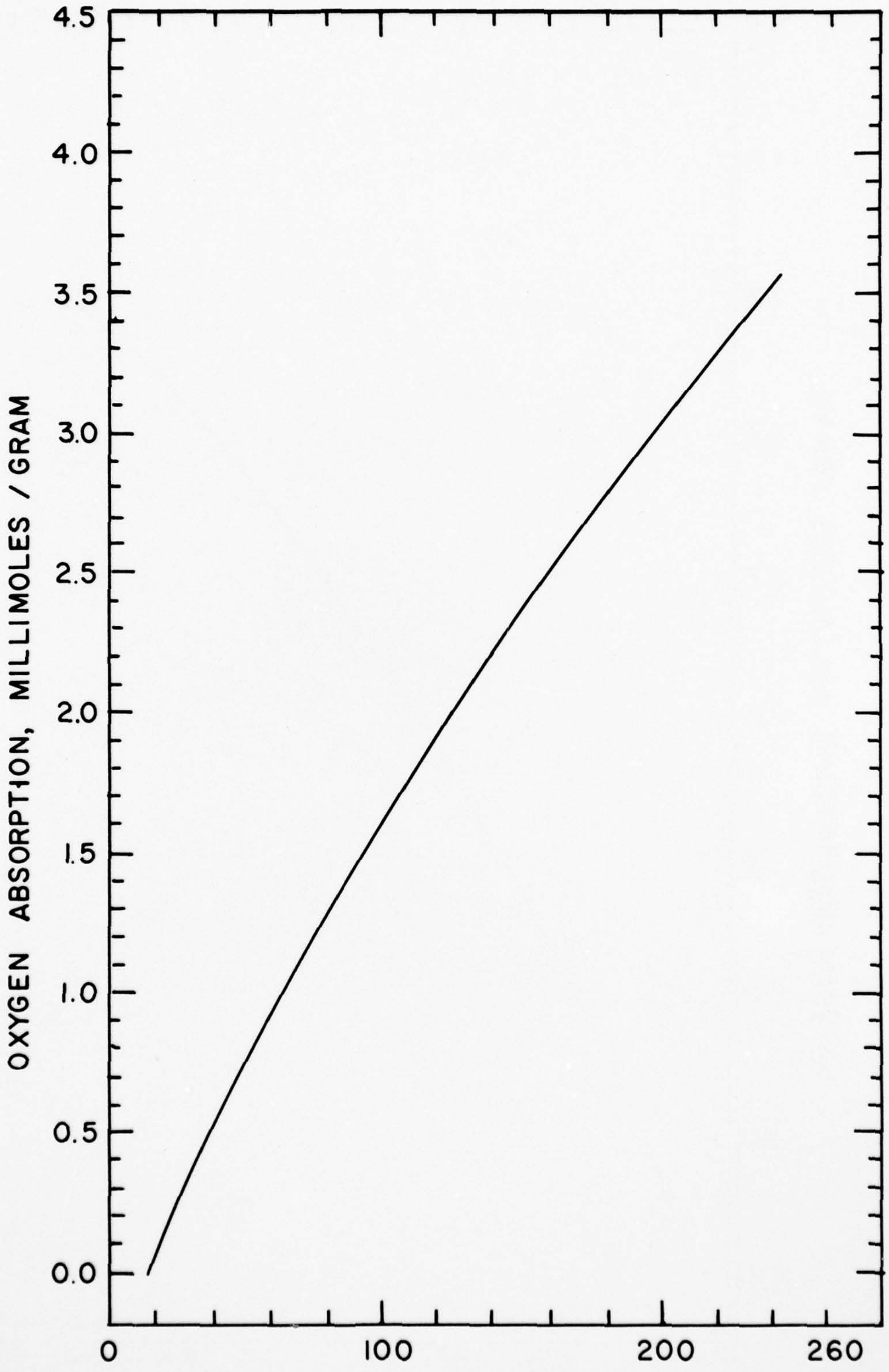

FIGURE 7. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F., 215 ml/min gas flow rate. RUN 1.

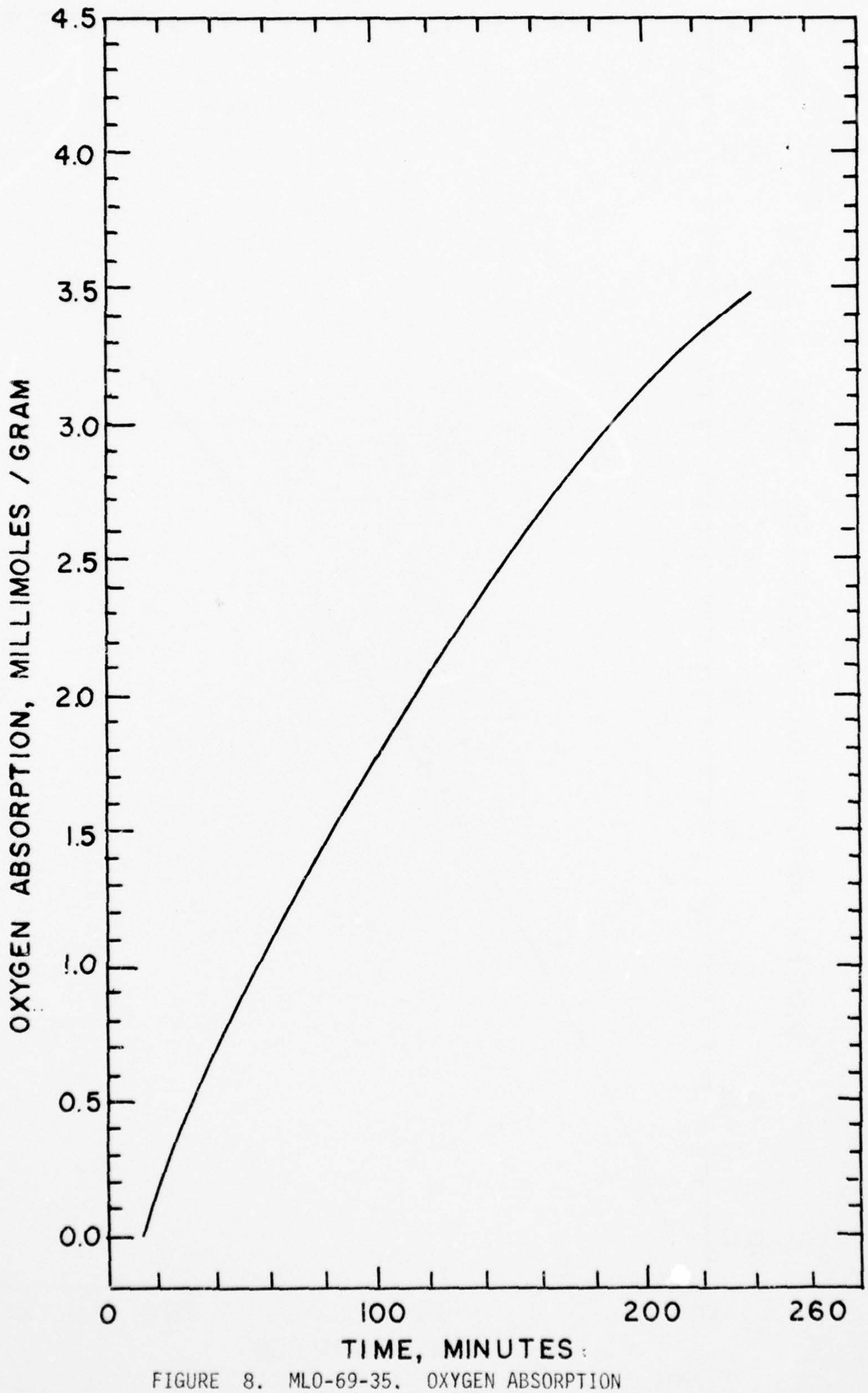

FIGURE 8. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 215 ml/min gas flow rate. RUN 2.

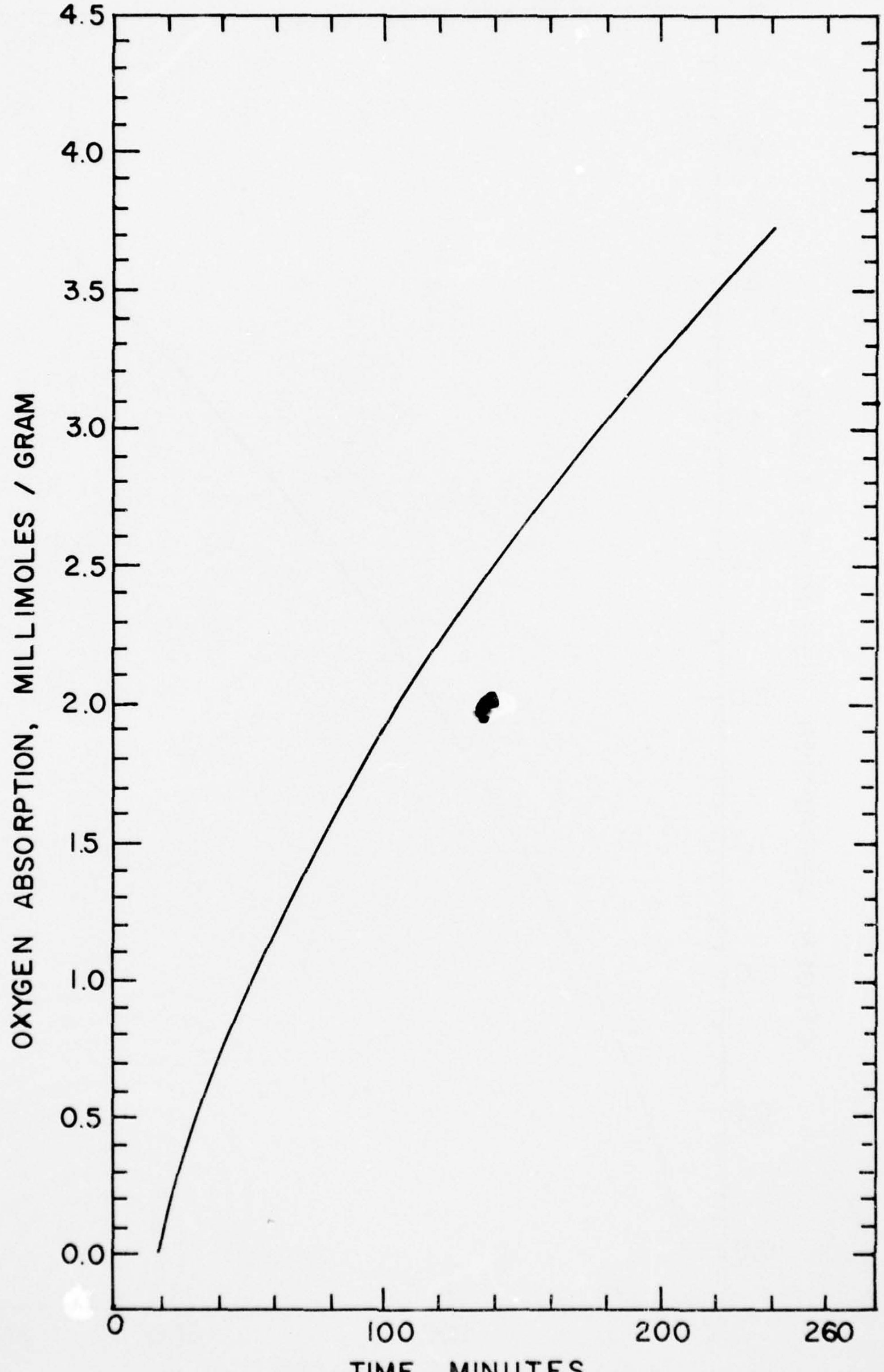

FIGURE 9. MLO-69-35. OXYGEN ABSORPTION
at 450 deg. F. 215 ml/min gas flow rate. RUN 3.

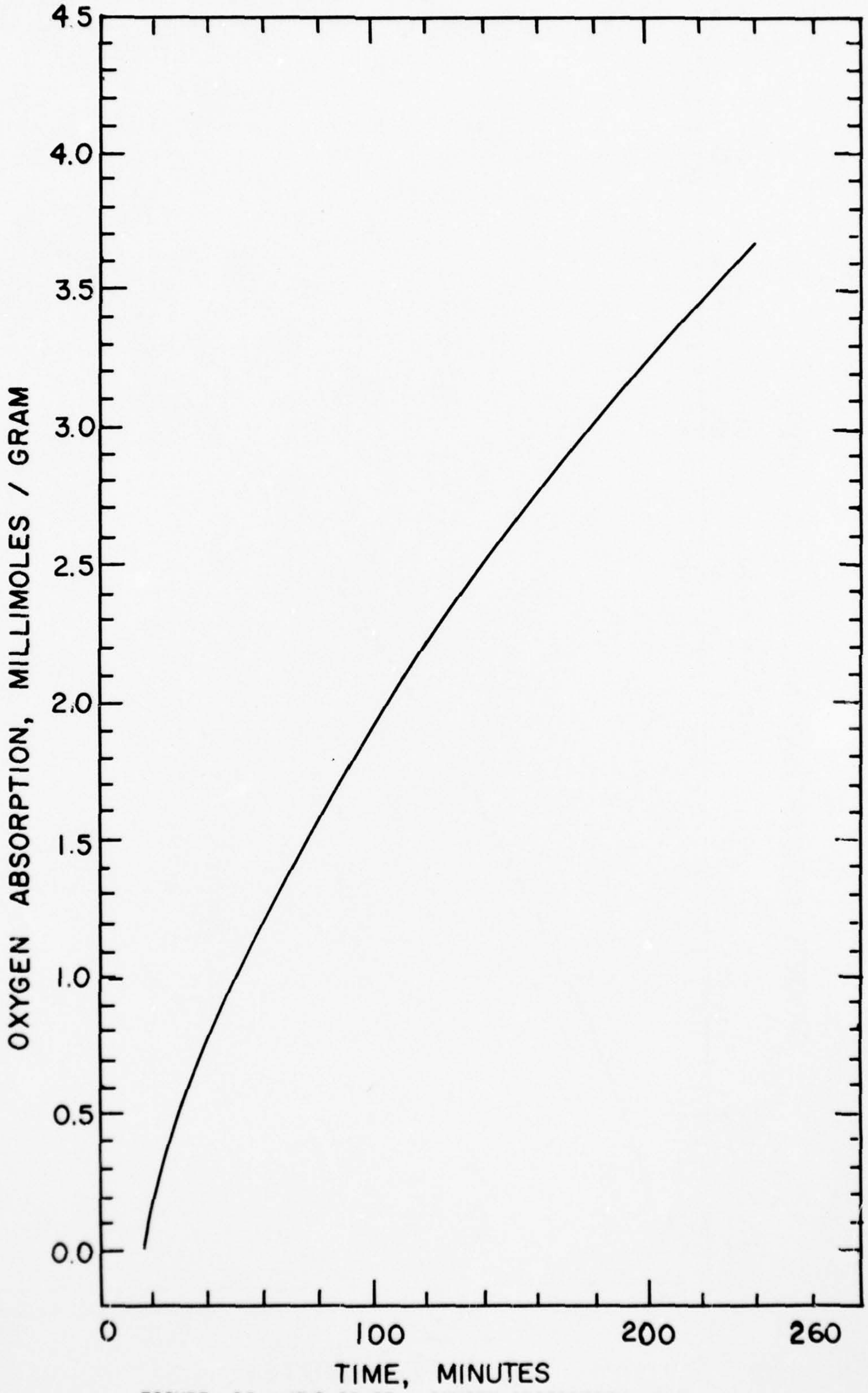

FIGURE 10. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 215 ml/min gas flow rate. RUN 4.

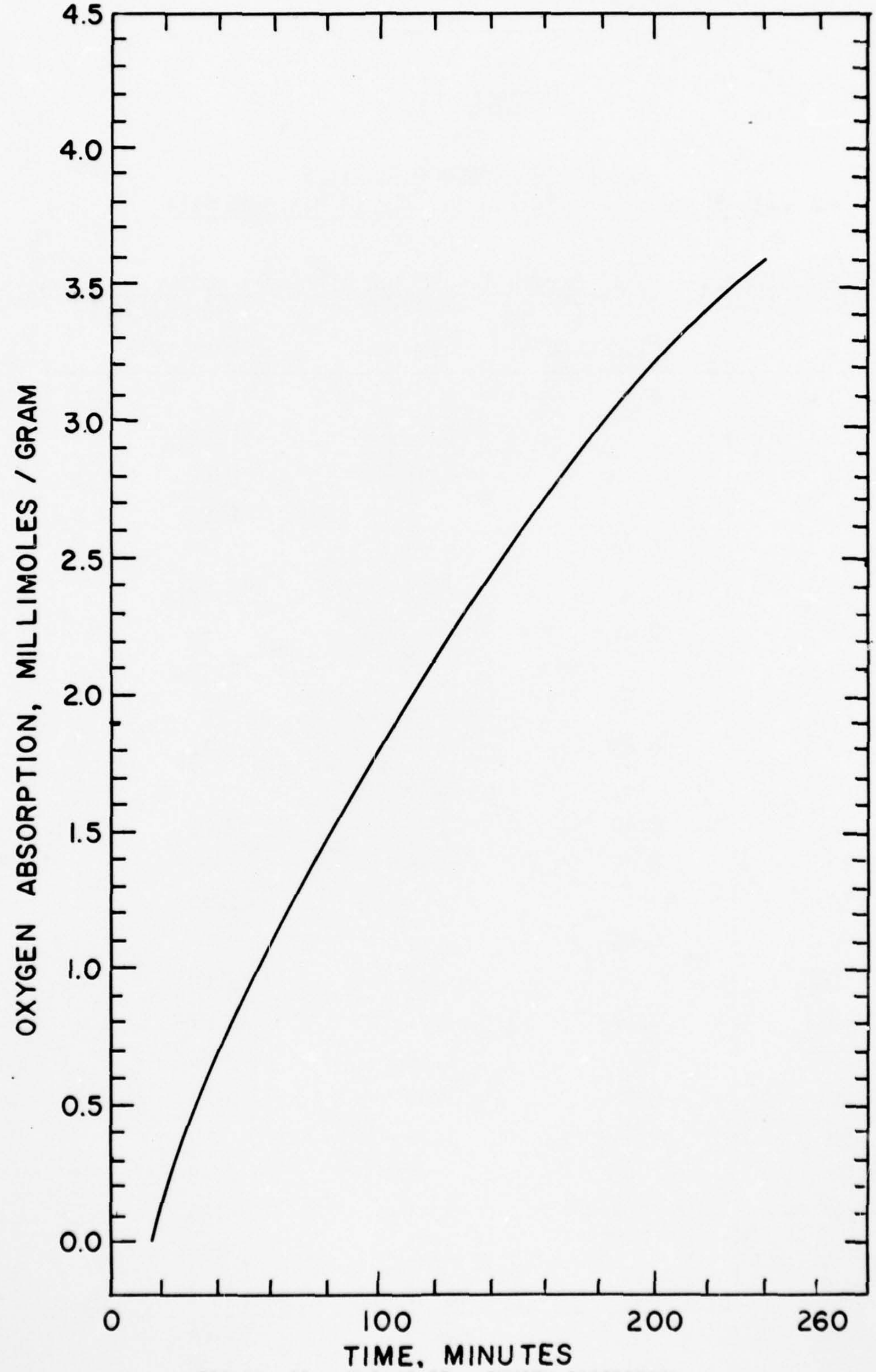

FIGURE 11. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 215 ml/min gas flow rate Average of 4 Determinations.

TABLE LI

MLO 69-35 OXYGEN ABSORPTION
at 450 deg. F., 48, 120 and 315 ml/min. GAS FLOW

Time, minutes (cumulative)	Total Oxygen Absorption millimols/gram		
	48 ml/min O_2 Flow rate	120 ml/min O_2 Flow rate	315 ml/min O_2 Flow rate
0	0	0	0
15	0	0	0.011
30	0.005	0.01	0.61
40	-	-	0.89
45	0.13	0.30	-
50	-	-	1.22
55	0.23	-	-
60	-	-	1.49
65	-	0.64	-
70	0.33	-	1.76
75	-	0.75	-
80	0.40	-	2.00
90	0.46	0.98	2.20
100	-	-	2.41
105	0.56	1.16	-
110	-	-	2.60
120	0.67	1.31	2.79
135	0.74	1.48	3.05
150	0.85	1.66	3.26
165	0.94	1.85	-
170	-	-	3.49
180	1.02	2.01	3.69
195	-	2.16	3.89
210	-	2.35	4.07
225	-	2.46	4.21
240	-	2.59	4.39

AD-A037 299 PHOENIX CHEMICAL LAB INC CHICAGO ILL F/G 11/8
CHEMICAL AND PHYSICAL PROPERTIES OF LUBRICANTS AND HYDRAULIC FL--ETC(U)
JUN 76 A A KRAWETZ, G A KRAWETZ, T TOVROG F33615-73-C-5103

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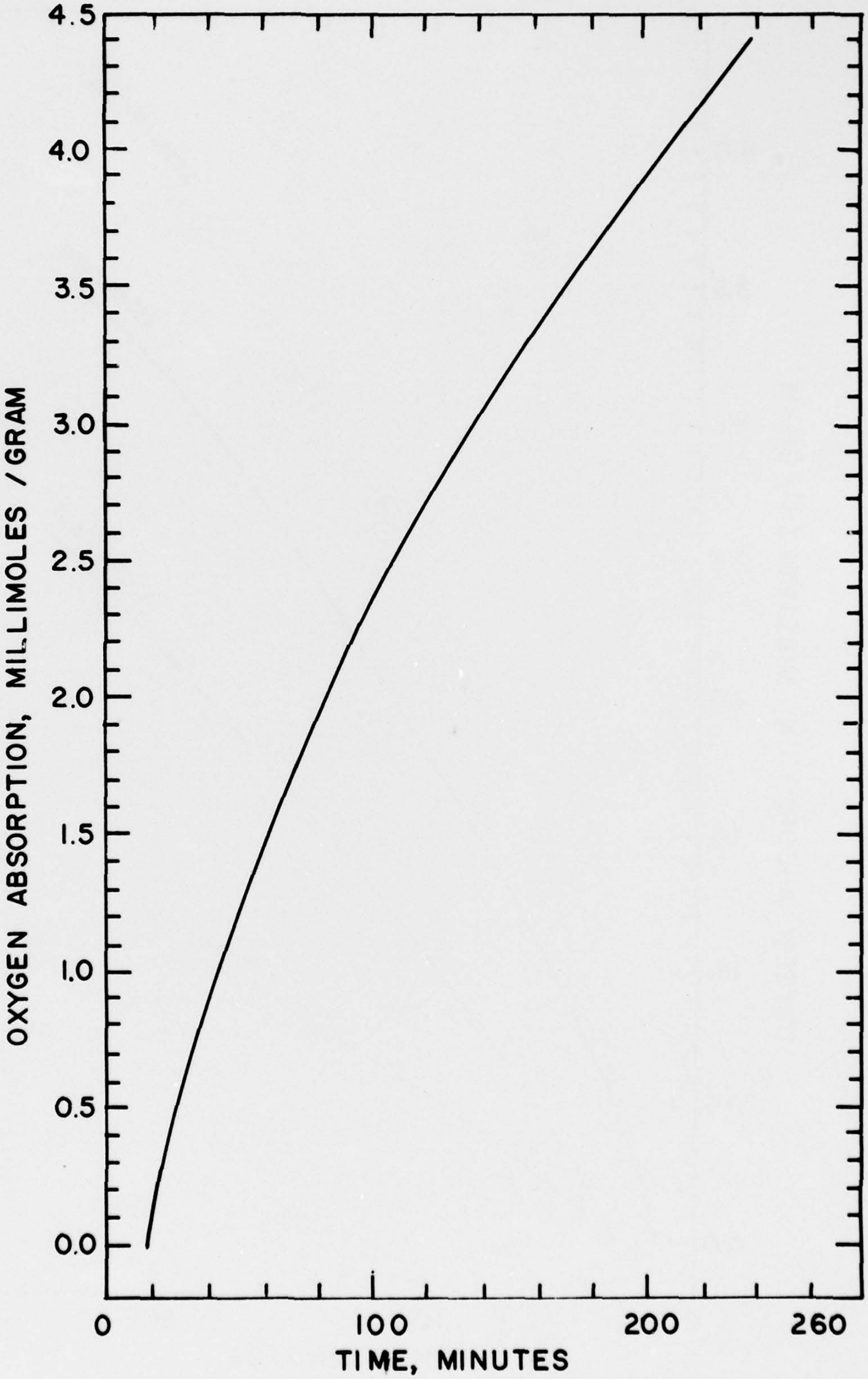

FIGURE 12. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. 315 ml/min gas flow rate

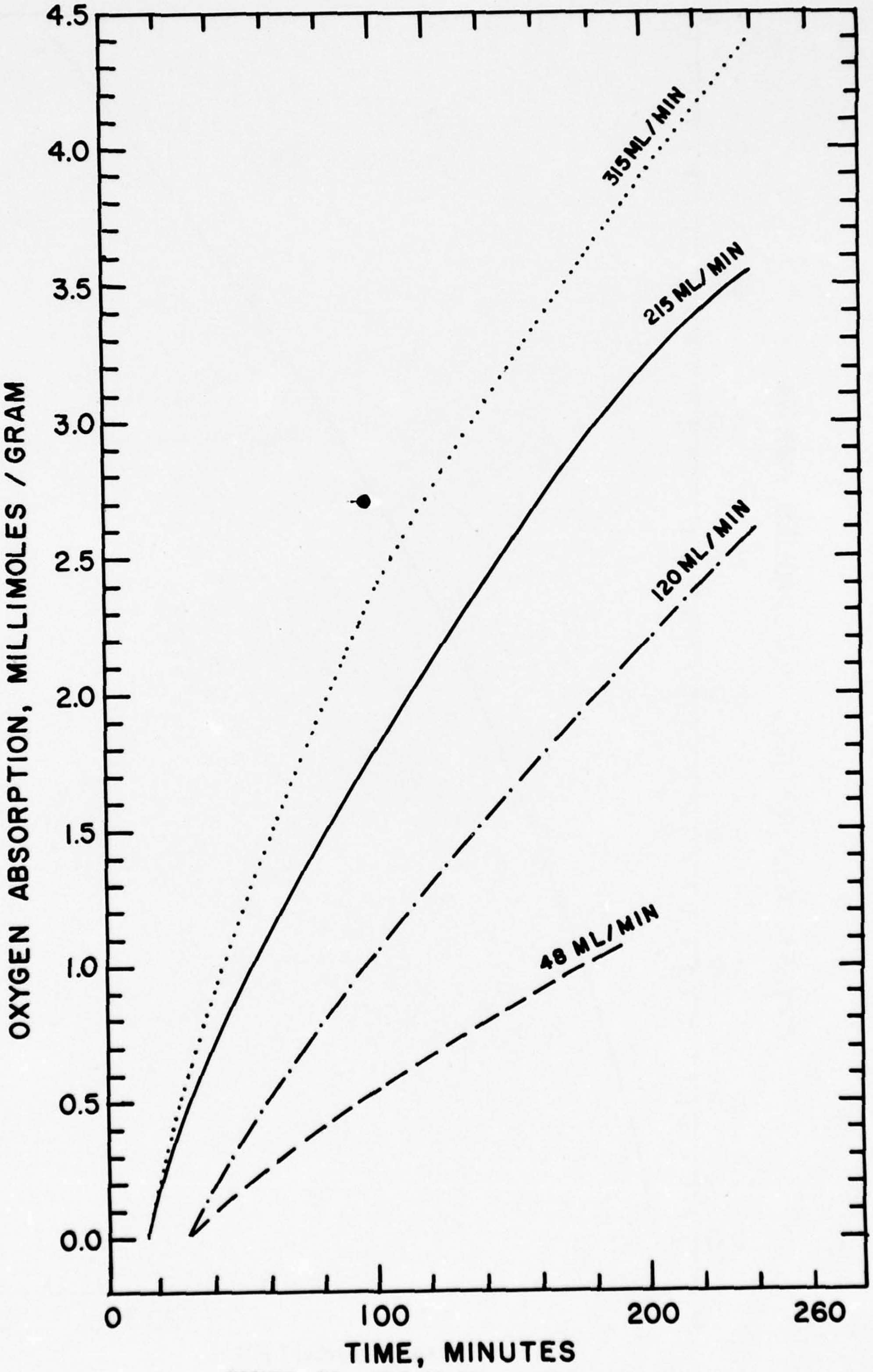

FIGURE 13. MLO-69-35. OXYGEN ABSORPTION at 450 deg. F. SUMMARY

TABLE LII

MLO-69-35

INDUCTION PERIODS @ 450 deg. F.

Oxygen Flow Rate, ml/min.		Induction Period, minutes
48		30
120		30
215	Run 1	15
215	Run 2	14.5
215	Run 3	15
215	Run 4	15
315		14.5

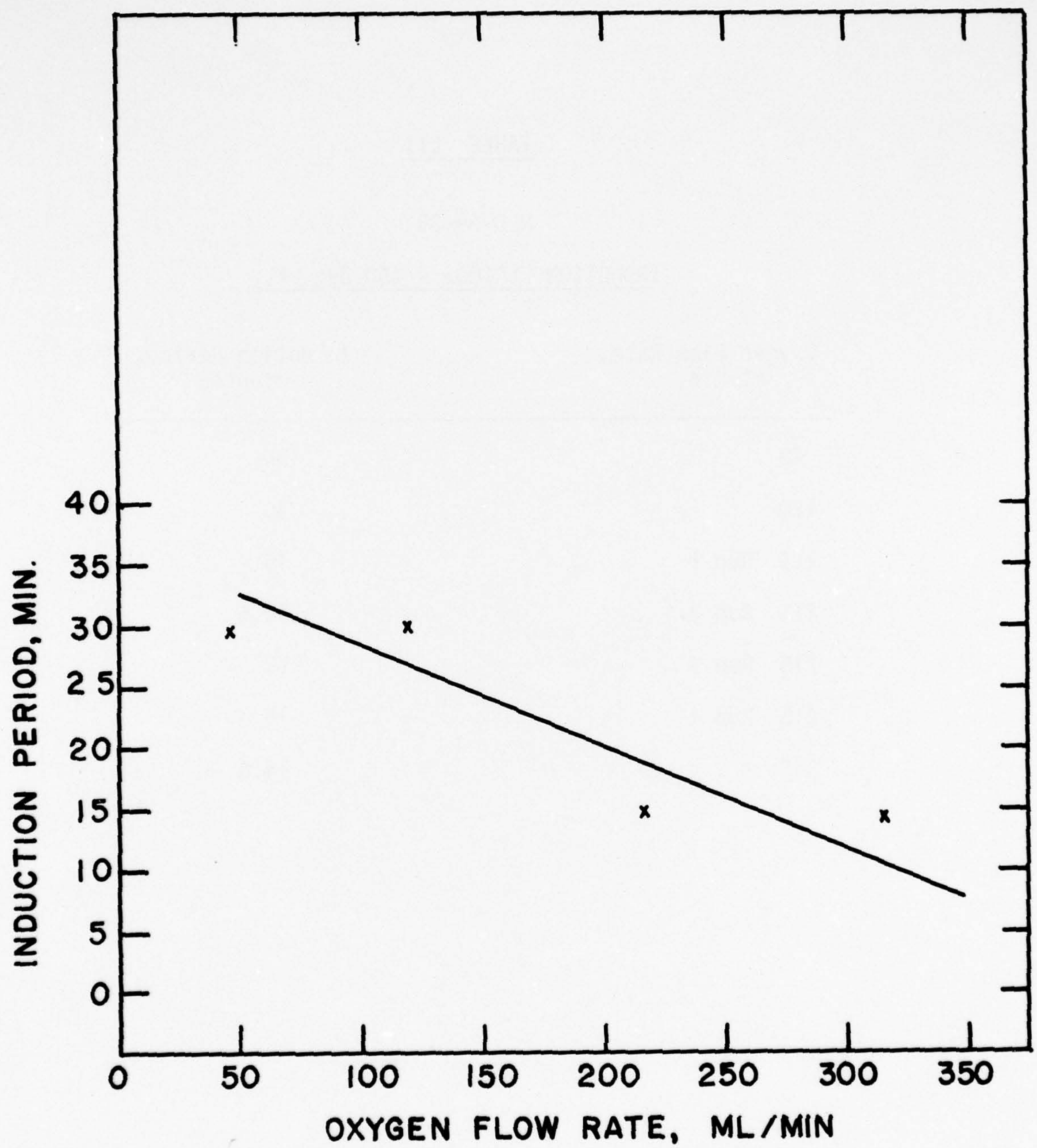

FIGURE 14. MLO-69-35. INDUCTION PERIODS at 450 deg. F.

TABLE LIII

MLO-69-35 OXYGEN ABSORPTION RATES
at 450 deg. F. 215 ml/min gas flow rate

Time interval, minutes	Absorption Rate, micromoles/gram/min. Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0 - 15	0.47	0.74	2.3	2.7	1.6	1.11	0.75
15 - 20	-	-	33.8	35.3	34.6	1.06	0.71
20 - 25	-	-	26.8	31.3	29.05	3.2	2.2
15 - 30	19.4	30.7	34.0	31.3	28.8	6.5	4.4
25 - 30	-	-	41.3	27.4	34.4	9.8	6.6
30 - 45	25.6	19.5	20.8	25.5	22.8	3.2	2.1
45 - 60	18.5	20.4	20.7	18.8	19.6	1.1	0.8
60 - 75	18.8	17.8	19.1	22.2	19.5	1.9	1.3
75 - 90	18.3	16.6	19.0	17.6	17.9	1.0	0.7
90 - 105	15.2	11.6	18.0	14.7	14.9	2.6	1.8
105 - 120	15.6	15.6	14.9	14.9	15.2	0.4	0.2
120 - 135	-	16.4	10.3	16.4	14.4	3.5	2.4
120 - 145	13.1	-	-	-	13.1	-	-
135 - 150	-	14.7	10.9	13.1	12.9	1.9	1.3
145 - 155	20.3	-	-	-	20.3	-	-
150 - 165	-	13.1	18.1	10.1	13.8	4.0	2.7
155 - 180	11.7	-	-	-	11.7	-	-
165 - 180	-	10.1	14.1	12.5	12.2	2.0	1.4
180 - 195	14.7	10.3	10.1	12.4	11.9	2.2	1.4
195 - 210	12.5	10.7	10.1	9.1	10.6	1.4	1.0
210 - 225	12.2	9.0	12.2	11.1	11.1	1.5	1.0
225 - 240	9.9	9.6	11.4	11.1	10.5	0.9	0.6

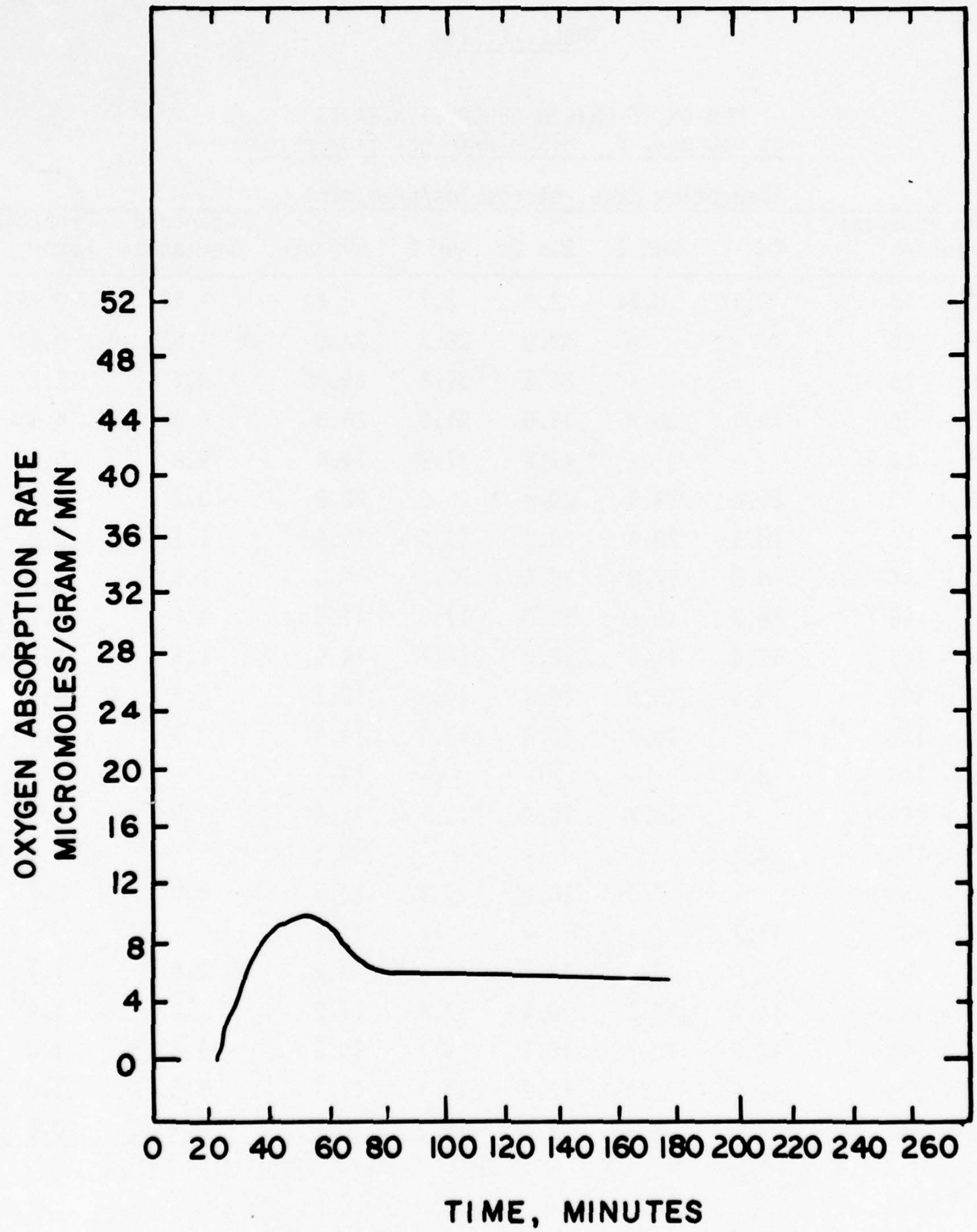

FIGURE 15. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 48 ml/min gas flow rate

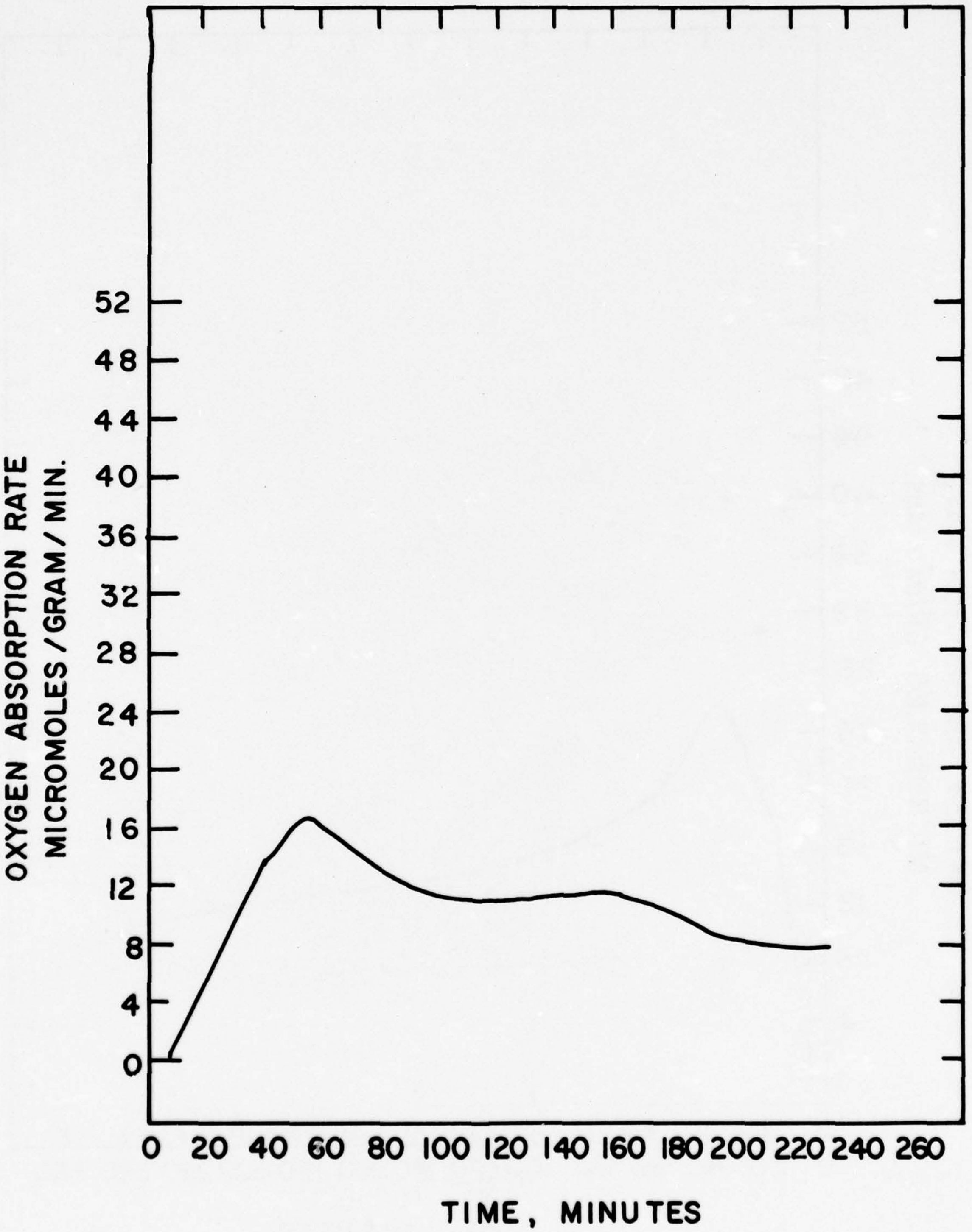

FIGURE 16. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 120 ml/min gas flow rate

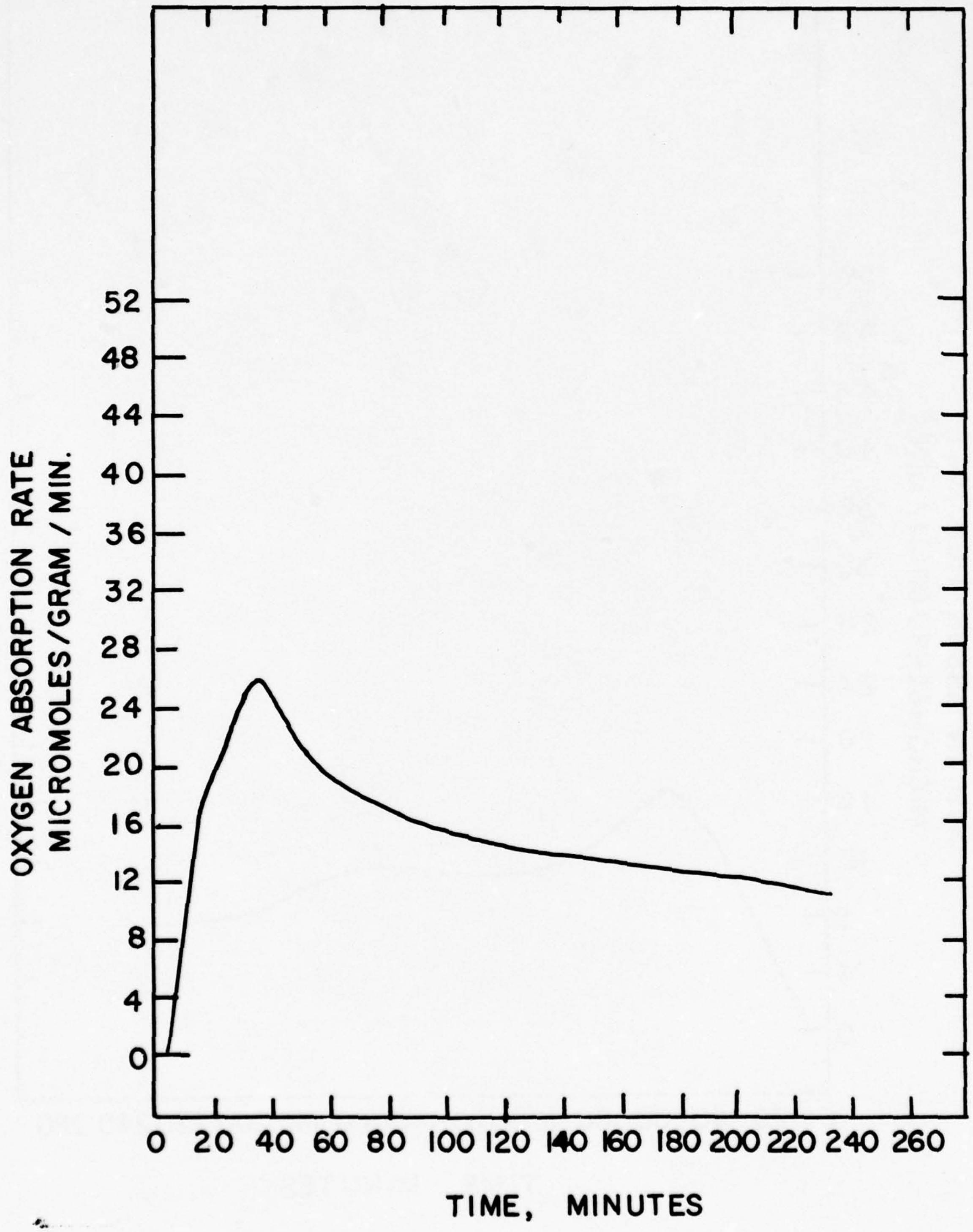

FIGURE 17. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 215 ml/min gas flow rate. RUN 1.

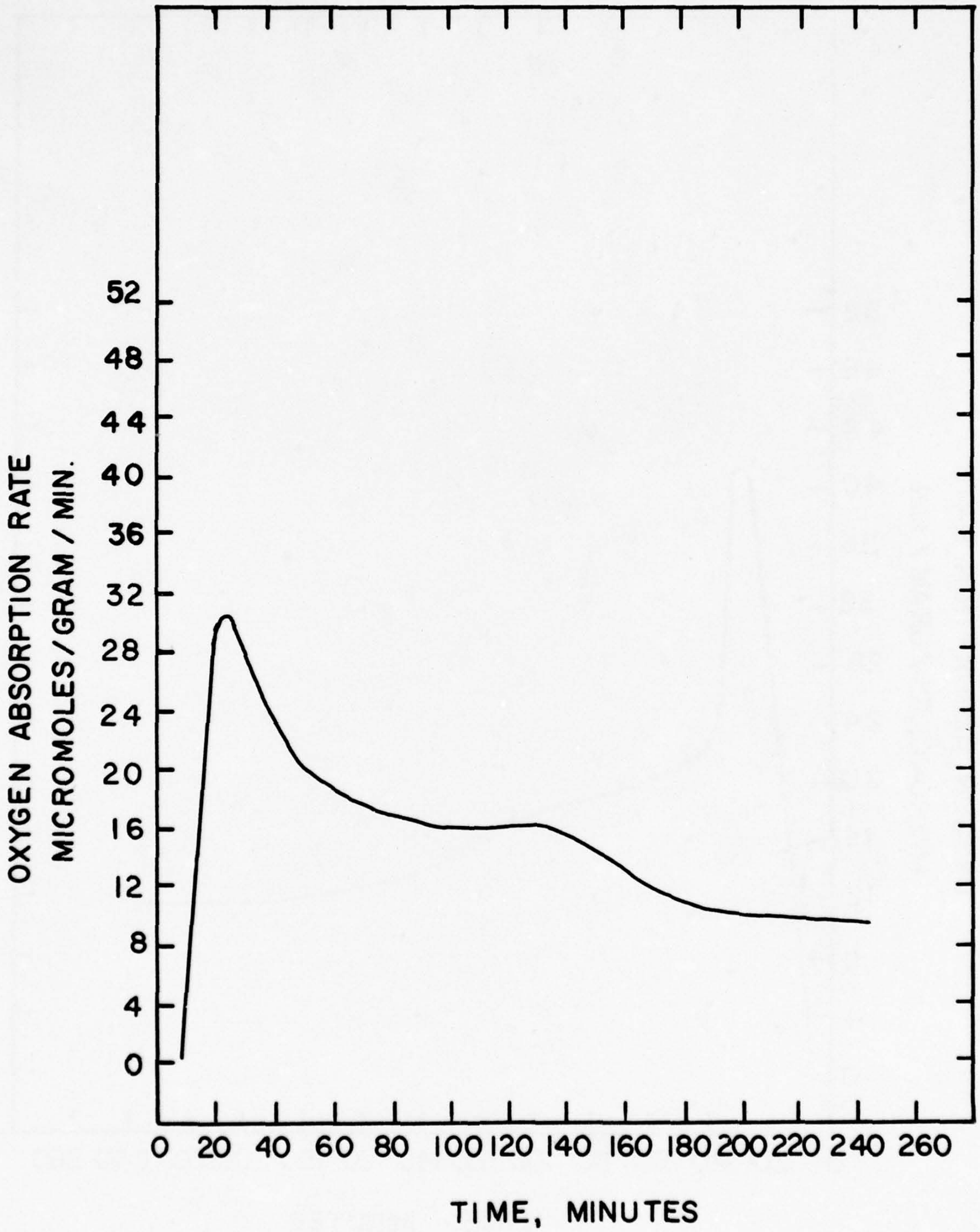

FIGURE 18. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 215 ml/min gas flow rate. RUN 2.

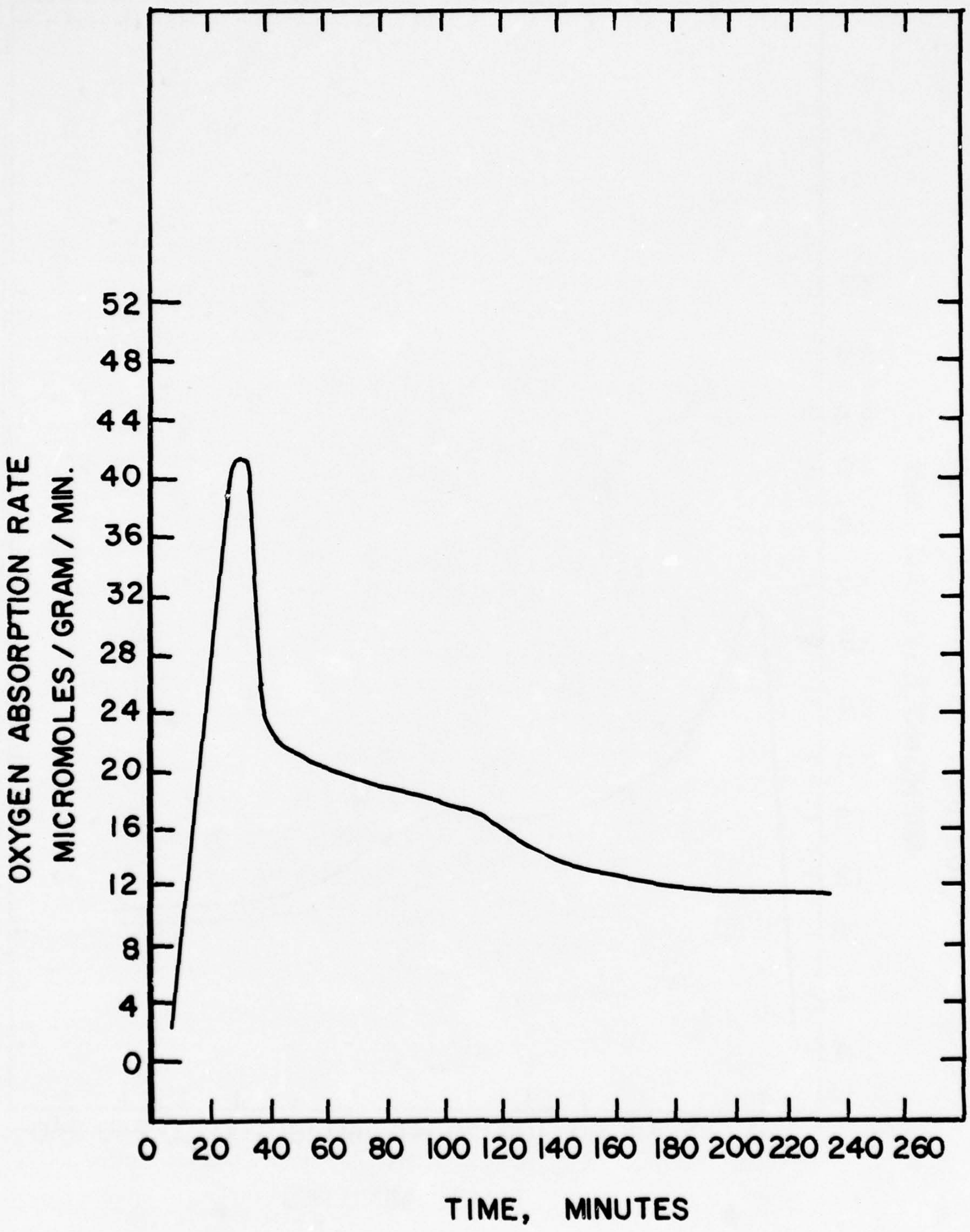

FIGURE 19. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 215 ml/min gas flow rate. RUN 3.

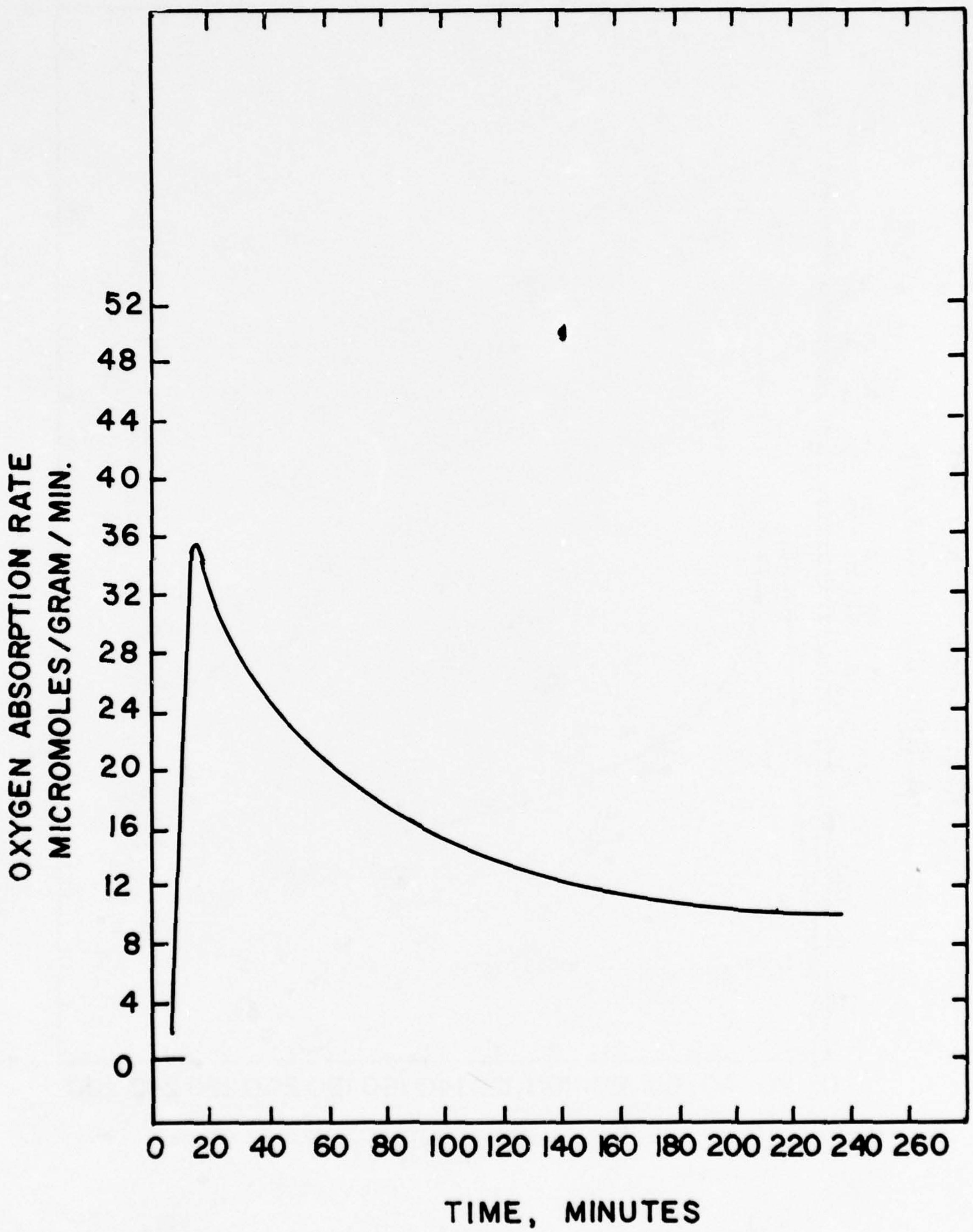

FIGURE 20. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 215 ml/min gas flow rate. RUN 4.

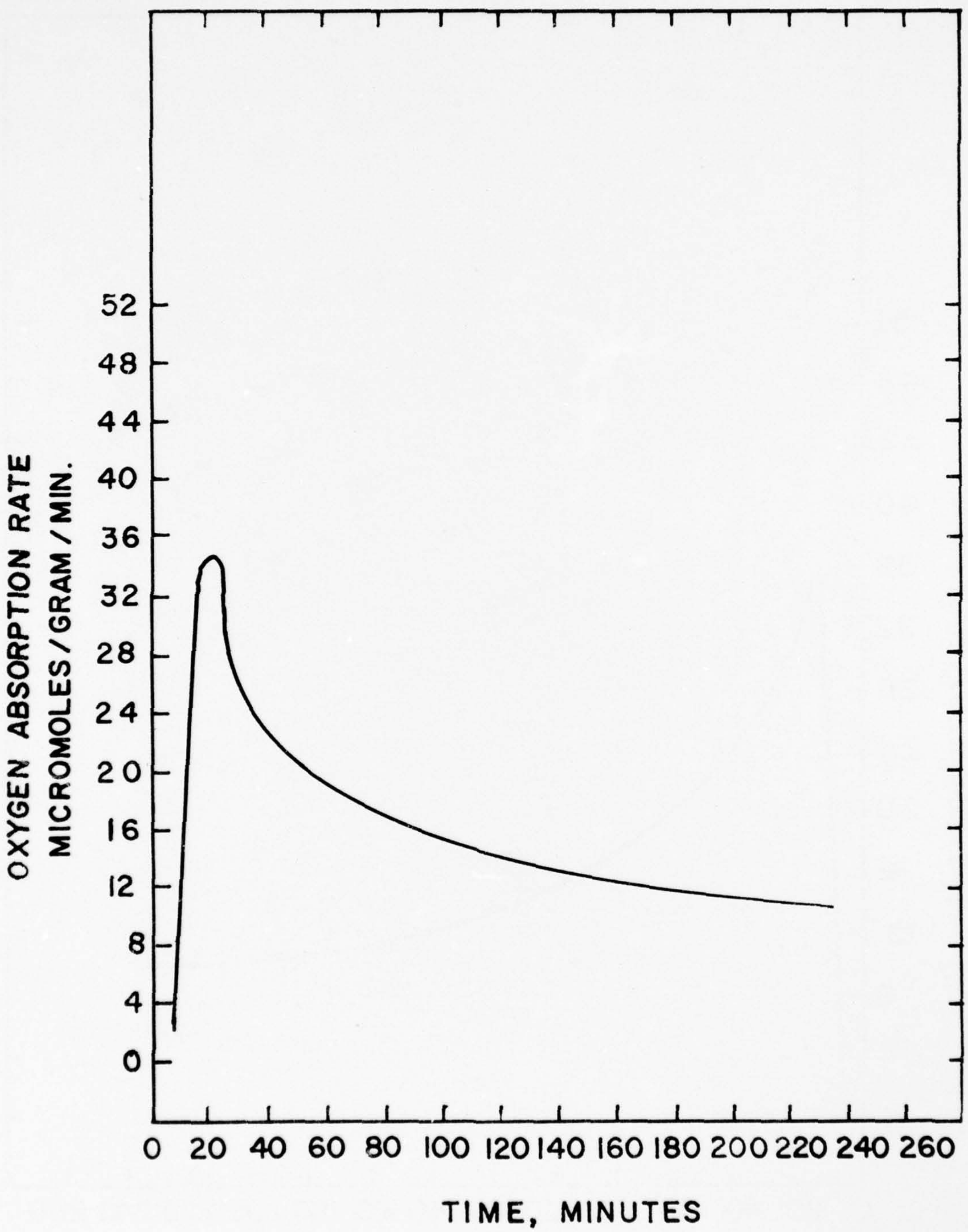

FIGURE 21. MLO 69-35. OXYGEN ABSORPTION RATES
450 deg. F. Average, 4 Determinations
at 215 ml/min gas flow rate.

TABLE LIV

MLO-69-35 OXYGEN ABSORPTION RATES
at 450 deg. F. 48, 120 and 315 ml/min gas flow rate

Oxygen Absorption Rate, micromoles/gram/min.

Time interval, minutes	48 ml/min O_2 flow rate	120 ml/min O_2 flow rate	315 ml/min O_2 flow rate
0 - 15	0	0	0.7
15 - 30	0.36	6.7	39.7
30 - 40	-	-	28.7
30 - 45	8.4	13.1	-
40 - 50	-	-	32.4
45 - 55	10.3	-	-
50 - 60	-	-	27.6
45 - 65	-	17.1	-
55 - 70	6.2	-	-
60 - 70	-	-	26.7
65 - 75	-	11.2	-
70 - 80	7.0	-	23.7
75 - 90	-	15.2	-
80 - 90	6.2	-	20.3
90 - 100	-	-	21.0
90 - 105	6.8	12.2	-
100 - 110	-	-	18.2
105 - 120	7.3	10.1	-
110 - 120	-	-	19.4
120 - 135	4.7	11.2	17.4
135 - 150	6.7	12.1	14.0
150 - 165	5.8	12.2	-
150 - 170	-	-	11.5
165 - 180	5.6	10.9	-
170 - 180	-	-	20.1
180 - 195	-	9.6	13.7
195 - 210	-	13.1	11.7
210 - 225	-	7.6	9.5
225 - 240	-	8.4	11.8

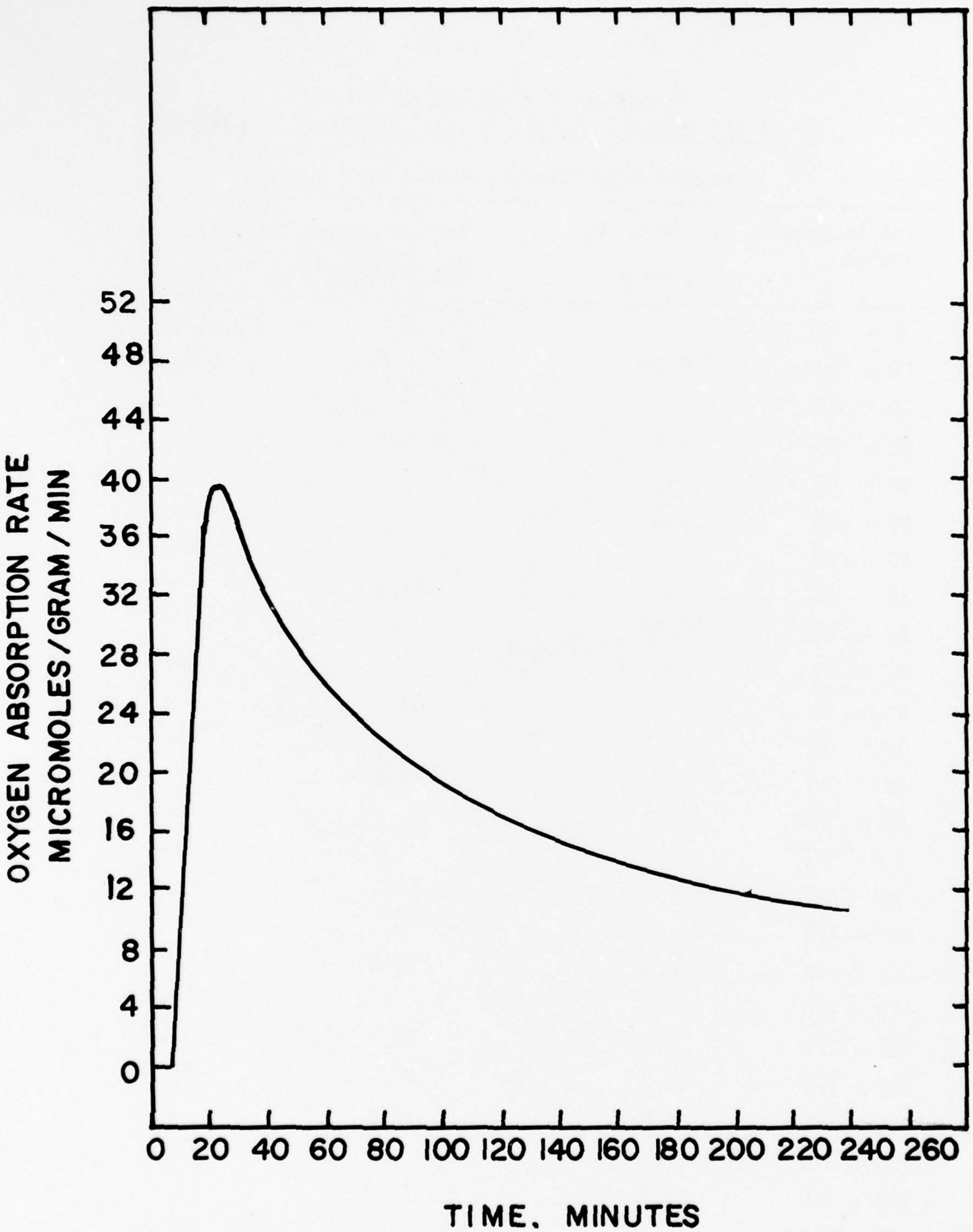

FIGURE 22. MLO-69-35. OXYGEN ABSORPTION RATES at 450 deg. F. 315 ml/min gas flow rate

TABLE LV

MLO-69-35 FINAL OXYGEN ABSORPTION RATES
after 240 min. at 450 deg. F.

Oxygen Flow Rate, ml/min.	Oxygen Absorption Rate, micromols/gram/min.
48*	5.6
120	8.4
215 Run 1	9.9
215 Run 2	9.6
215 Run 3	11.4
215 Run 4	11.1
215 Average (4 Runs)	10.5
315	11.8

* Test duration: 180 min.

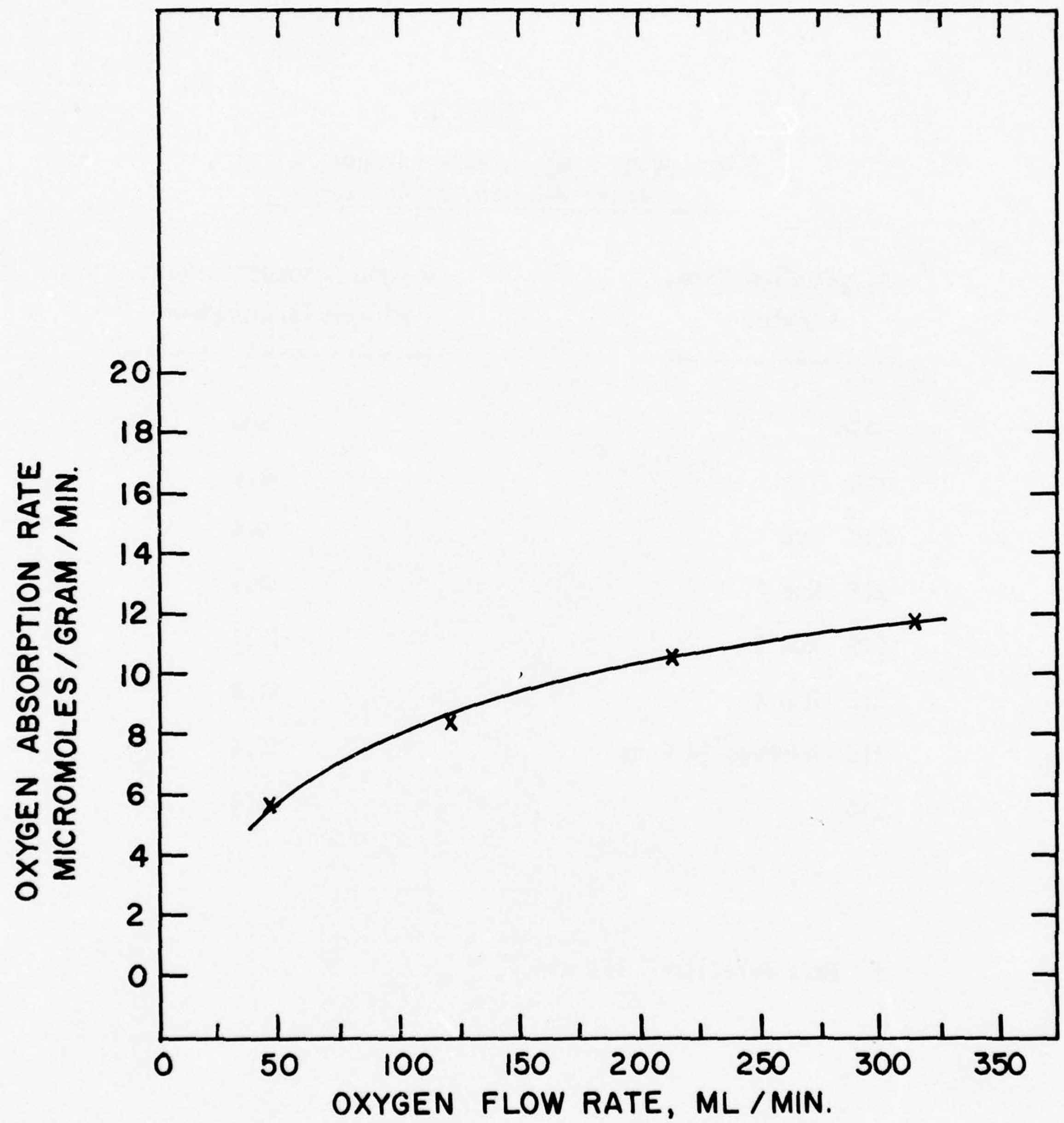

FIGURE 23. MLO-69-35. FINAL OXYGEN ABSORPTION RATES after 240 min. at 450 deg. F. (48 ml/min test, 180 min.)

TABLE LVI

MLO-69-35

OIL PROPERTIES AFTER OXYGEN ABSORPTION TESTS at 450 deg. F.

ORIGINAL OIL

Acid No., mg KOH/gram	0.07
Viscosity @ 100 deg. F., cs.	24.64

After Oxidation Absorption Test, 450 deg. F., 240 min.

Oxygen Flow Rate ml/min.	Acid No. mg.KOH/ gram	Viscosity @ 100 deg. F., cs.	Viscosity Increase, cs.	Viscosity Increase, %
48*	8.37	45.44	20.80	84.4
120	30.67	108.58	83.94	341
215 Run 1	33.97	265.22	240.58	976
215 Run 2	32.24	219.6	194.36	789
215 Run 3	31.06	257.6	232.96	946
215 Run 4	24.73	278.3	253.66	1,030
215 (4 Run Average)	30.50	255.18	230.39	935
315	40.23	886.65	862.01	3,498

* Test Duration: 180 min.

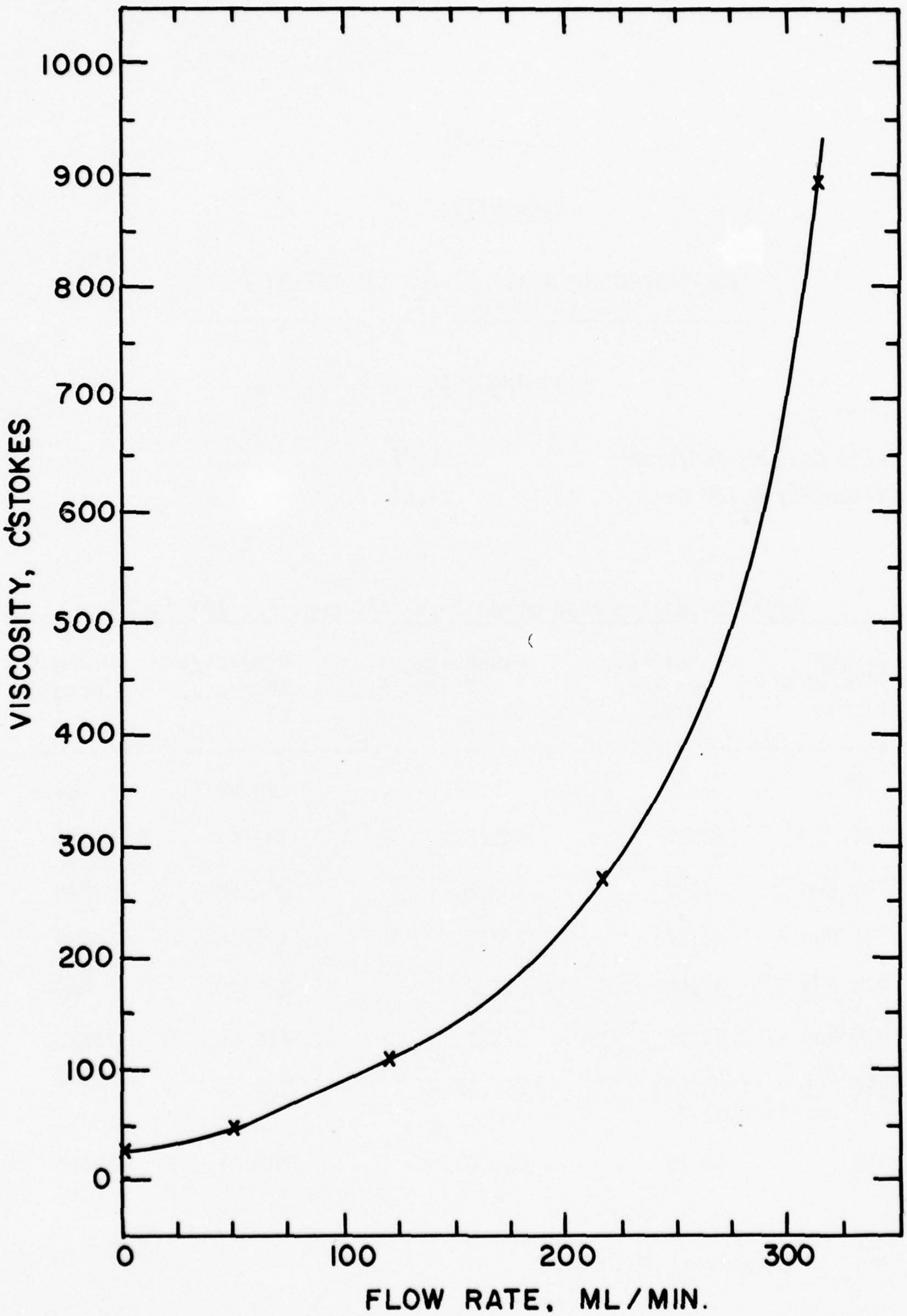

FIGURE 24. MLO-69-35. VISCOSITY AFTER OXYGEN ABSORPTION TEST at 450 deg. F. for 4 Hours (48 ml/min test, 3 Hours)

TABLE LVII

MLO-69-35 OXYGEN ABSORPTION
at 400 deg. F., 215 ml/min gas flow rate

Total minutes (cumulative)	Total Oxygen Absorption, millimoles/gram						
	Run 1	Run 2	Run 3	Run 4	Average	Probable Error	Standard Deviation
15	-	-	0.002	0.002	0.002	-	-
20	0.04	0.04	0.06	0.08	0.06	0.02	0.01
25	0.18	0.17	0.16	0.18	0.17	0.01	0.01
30	0.26	0.26	0.33	0.31	0.29	0.04	0.02
45	0.54	0.58	0.52	0.60	0.56	0.04	0.02
60	0.78	0.88	0.83	0.87	0.84	0.05	0.03
75	1.06	1.17	1.13	1.19	1.14	0.06	0.04
90	1.32	1.43	1.39	1.47	1.40	0.06	0.04
105	1.57	1.67	1.66	1.74	1.66	0.07	0.05
120	1.78	1.88	1.90	1.95	1.87	0.07	0.05
135	2.00	2.07	2.16	2.18	2.10	0.08	0.06
150	2.18	2.26	2.35	2.36	2.29	0.08	0.06
165	2.37	2.42	2.53	2.59	2.48	0.10	0.07
180	2.54	2.57	2.72	2.74	2.64	0.10	0.07
195	2.73	2.72	2.92	2.92	2.82	0.11	0.08
210	2.89	2.89	3.08	3.10	2.99	0.12	0.08
225	3.06	3.05	3.22	3.24	3.14	0.10	0.07
240	3.21	3.19	3.36	3.37	3.28	0.10	0.06

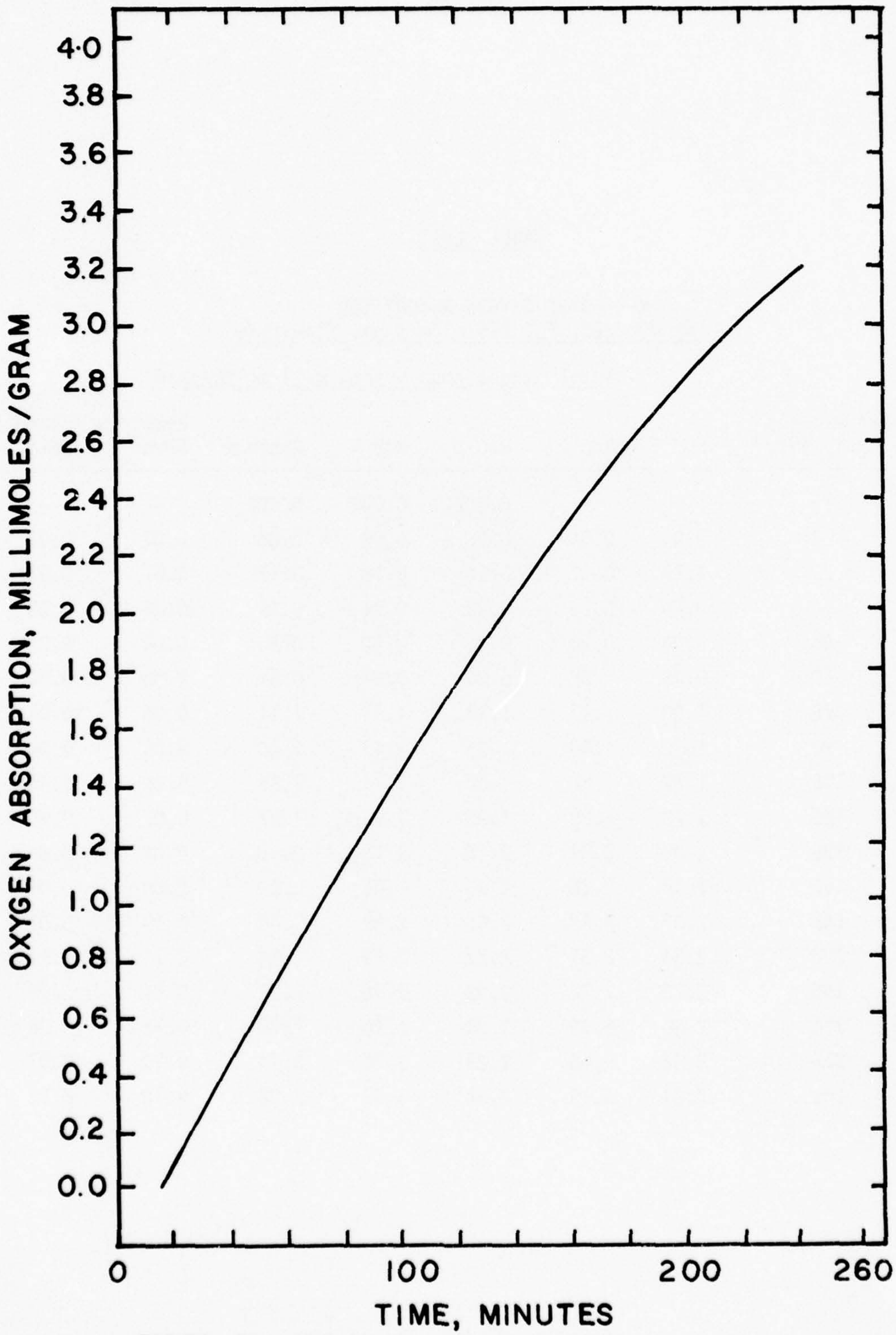

FIGURE 25. MLO-69-35. OXYGEN ABSORPTION
at 400 deg. F. 215 ml/min gas flow rate. RUN 1.

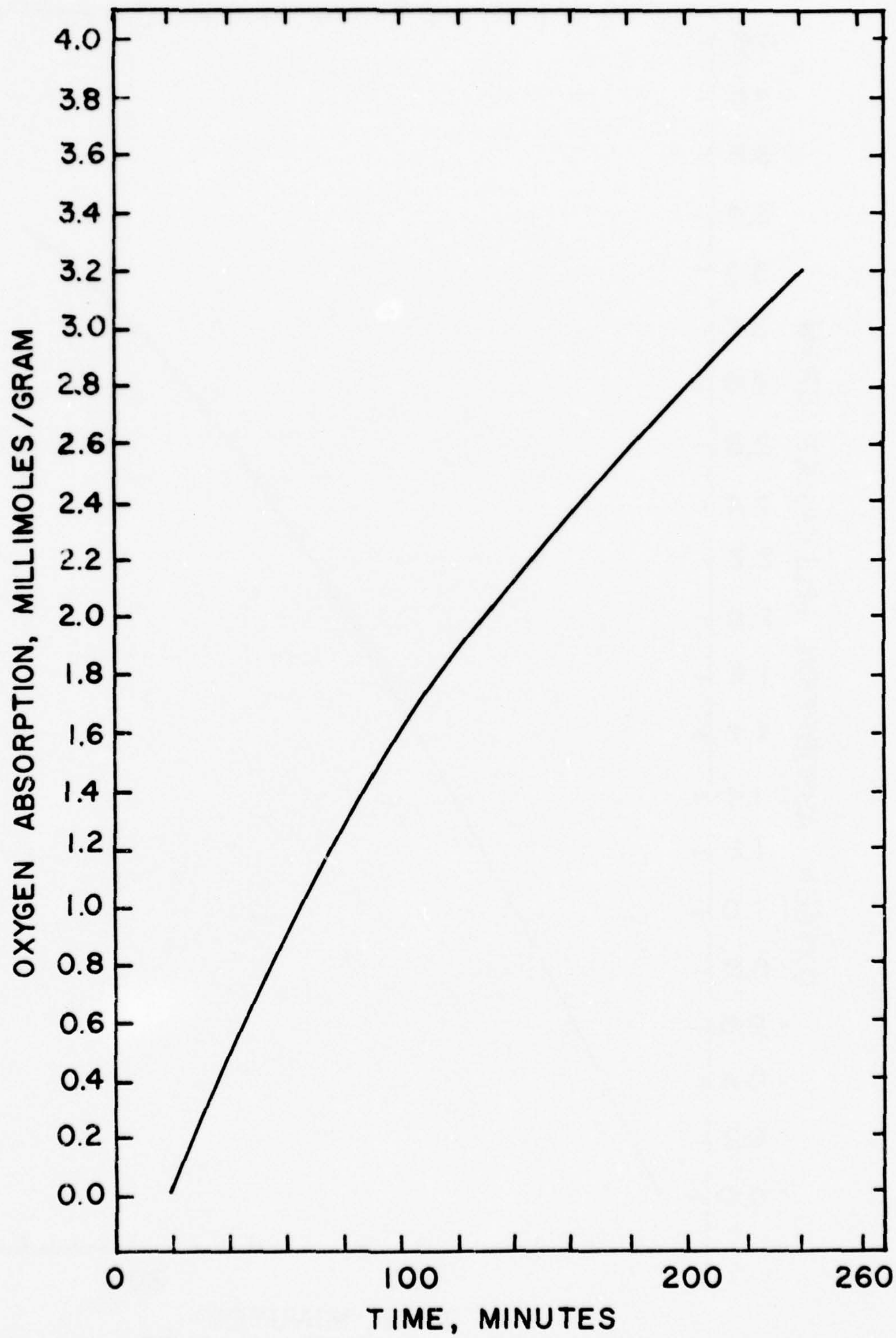

FIGURE 26. MLO-69-35. OXYGEN ABSORPTION at 400 deg. F. 215 ml/min gas flow rate. RUN 2.

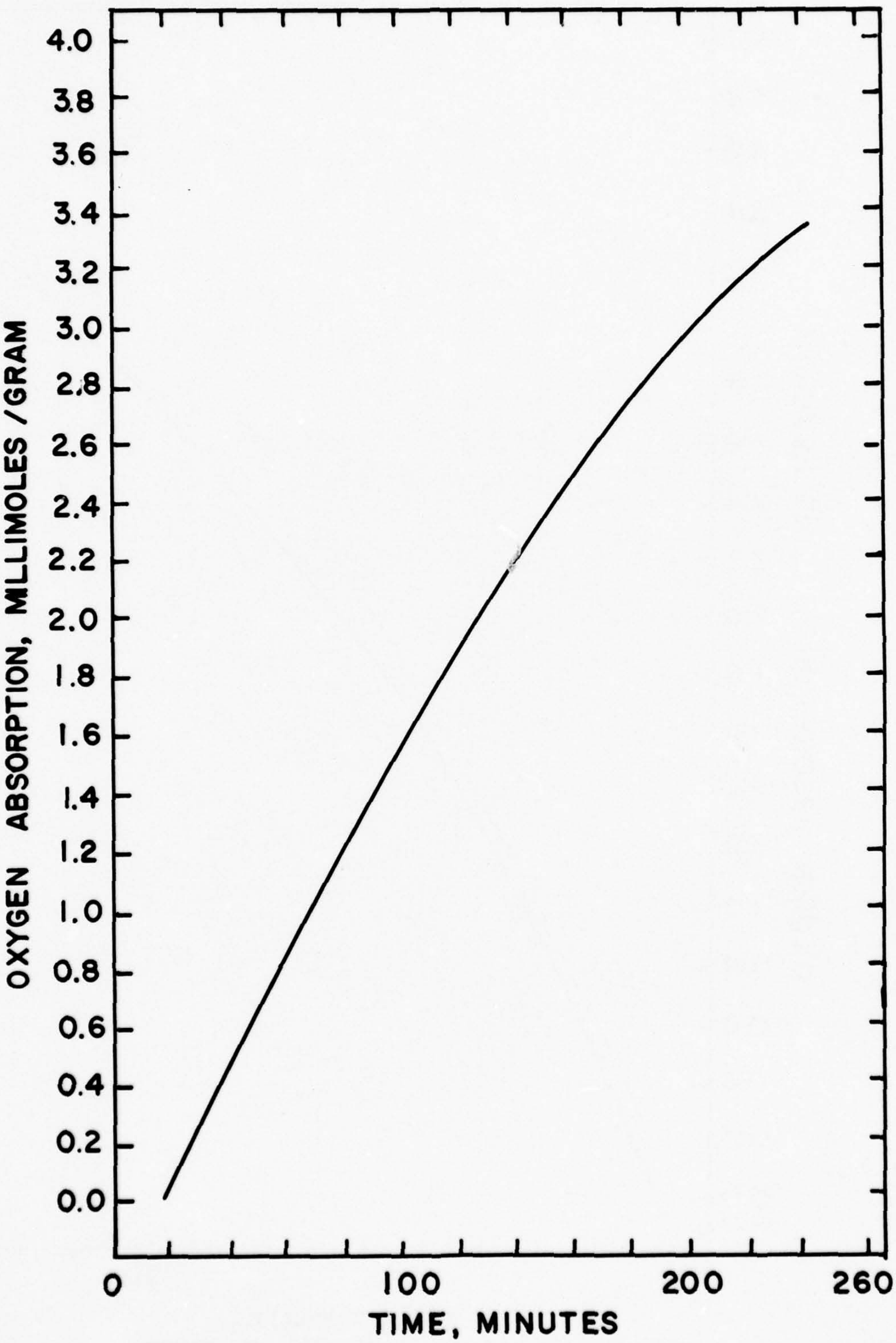

FIGURE 27. MLO-69-35. OXYGEN ABSORPTION at 400 deg. F. 215 ml/min gas flow rate. RUN 3.

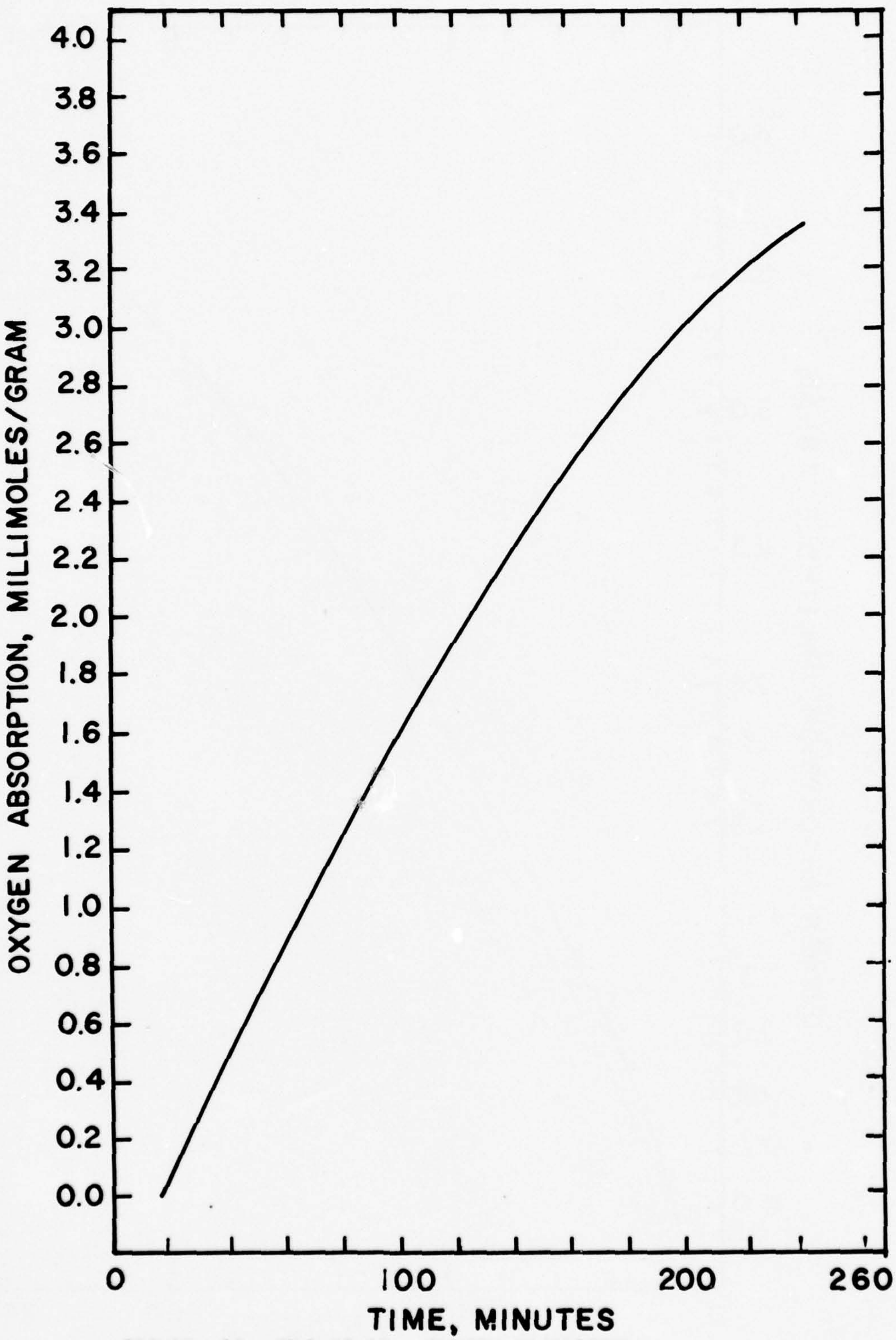

FIGURE 28. MLO-69-35. OXYGEN ABSORPTION at 400 deg. F. 215 ml/min gas flow rate. RUN 4.

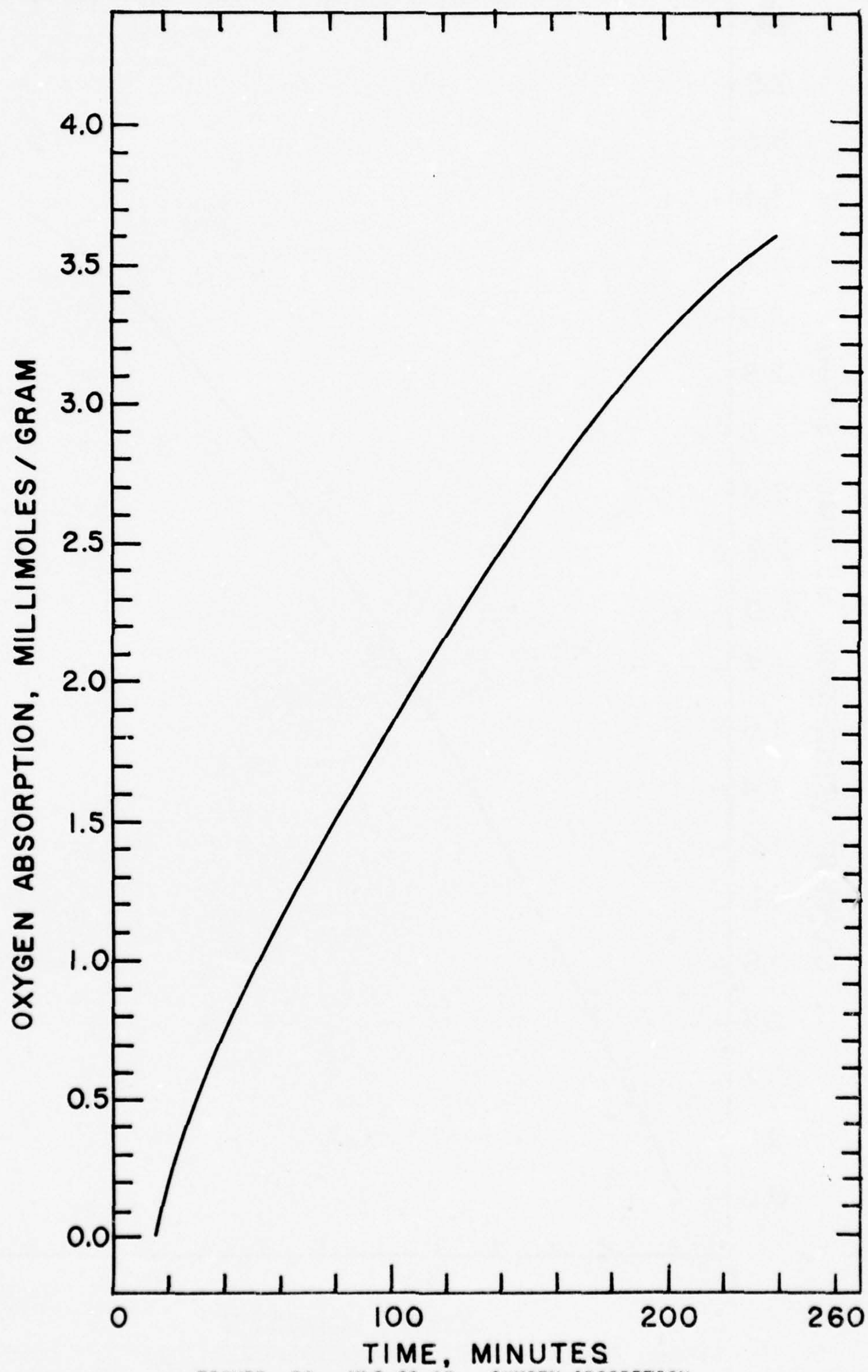

FIGURE 29. MLO-69-35. OXYGEN ABSORPTION
at 400 deg. F. 215 ml/min gas flow rate
Average of 4 Runs.

TABLE LVIII

MLO-69-35 OXYGEN ABSORPTION RATE
at 400 deg. F., 215 ml/min gas flow rate

Time Interval, minutes	Run 1	Run 2	Run 3	Run 4	Average	Probable Error	Standard Deviation
	Oxygen Absorption Rate, micromoles/gram/min.						
0 - 15	-	-	0.10	0.16	0.13	0.04	0.03
15 - 20	8.58	6.91	11.68	14.94	10.53	3.54	2.39
20 - 25	27.57	26.86	19.46	21.14	23.76	4.06	2.74
25 - 30	16.77	18.91	33.68	25.91	23.82	7.65	5.16
30 - 45	18.49	21.19	12.68	19.39	17.94	3.68	2.48
45 - 60	16.13	20.16	20.86	17.78	18.73	2.18	1.47
60 - 75	18.28	18.89	19.88	21.06	19.53	1.22	0.82
75 - 90	17.75	17.24	17.71	18.81	17.88	0.66	0.45
90 - 105	16.11	16.40	17.87	17.96	17.08	0.97	0.65
105 - 120	14.01	13.93	16.18	14.20	14.58	1.07	0.72
120 - 135	15.02	12.64	17.02	15.15	14.96	1.80	1.21
135 - 150	12.13	12.69	12.76	12.32	12.47	0.31	0.21
150 - 165	12.30	10.57	12.15	15.23	12.56	1.94	1.31
165 - 180	11.58	9.91	12.63	10.25	11.09	1.25	0.85
180 - 195	12.16	9.85	13.03	11.95	12.00	1.53	1.03
195 - 210	11.07	11.39	10.51	11.63	11.15	0.48	0.33
210 - 225	11.02	11.07	9.74	9.27	10.28	0.91	0.61
225 - 240	10.20	9.03	9.16	8.80	9.30	0.62	0.42

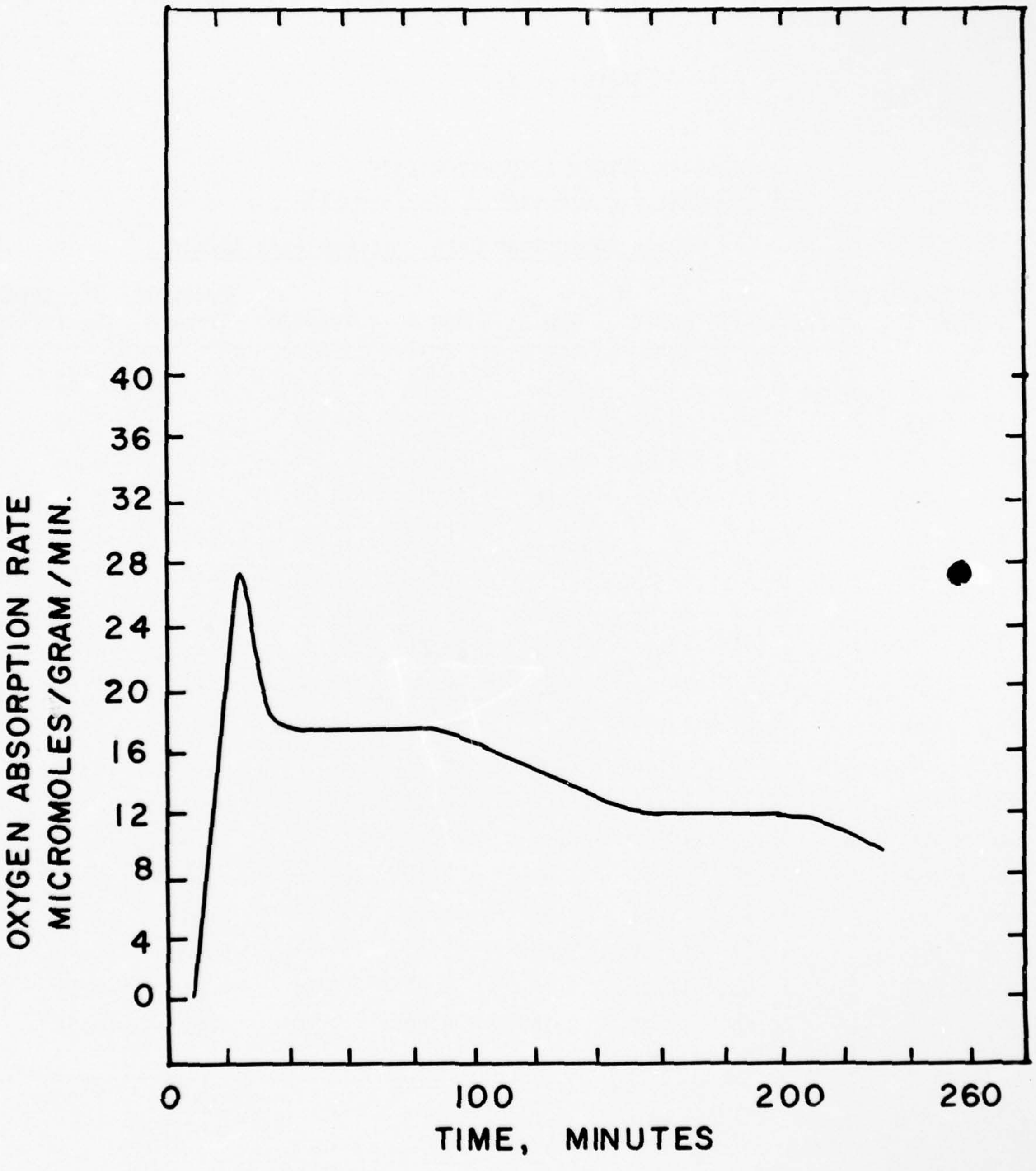

FIGURE 30. MLO-69-35. OXYGEN ABSORPTION RATES
at 400 deg. F. 215 ml/min gas flow rate. RUN 1

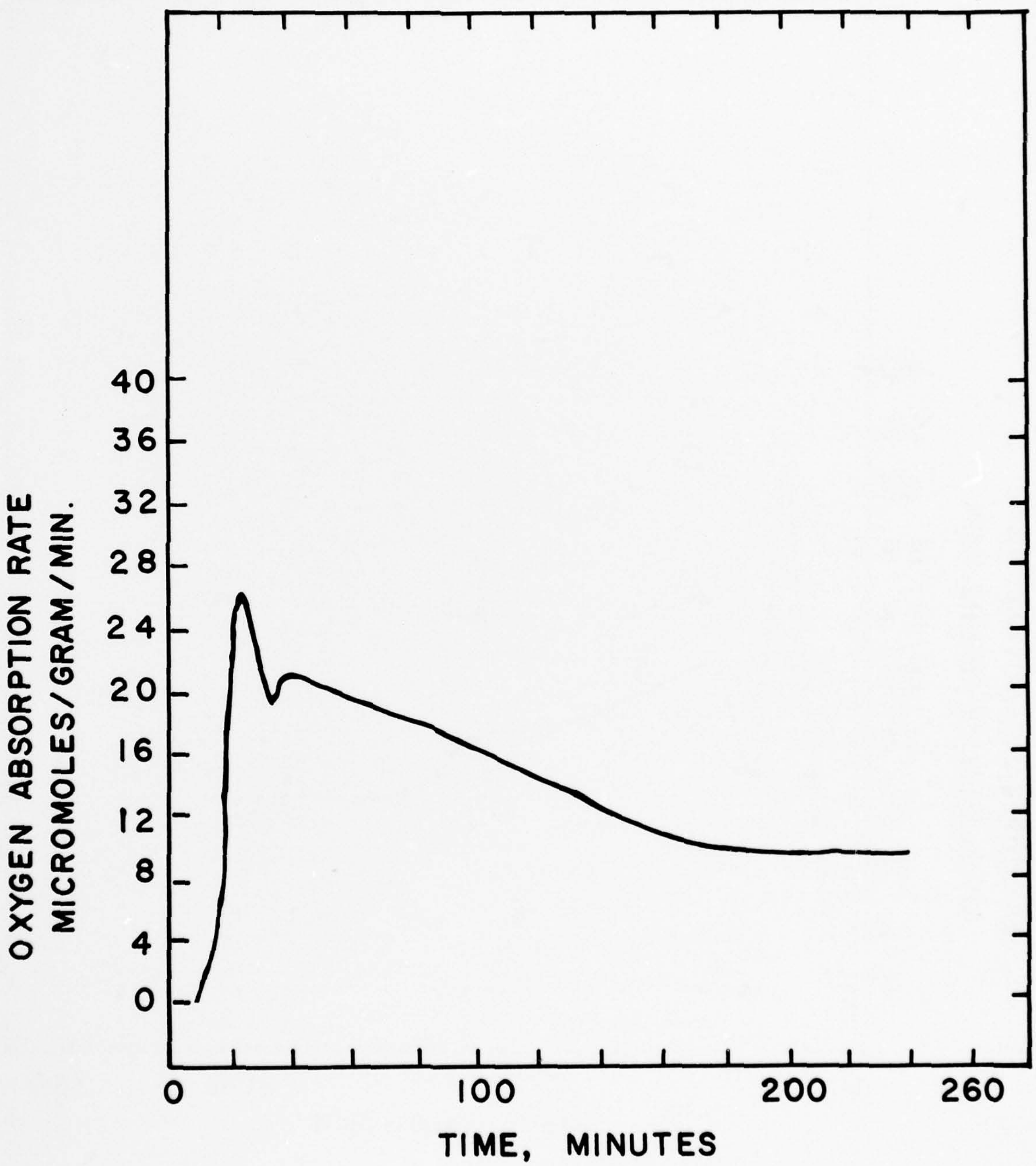

FIGURE 31. MLO-69-35. OXYGEN ABSORPTION RATES
at 400 deg. F. 215 ml/min gas flow rate. RUN 2.

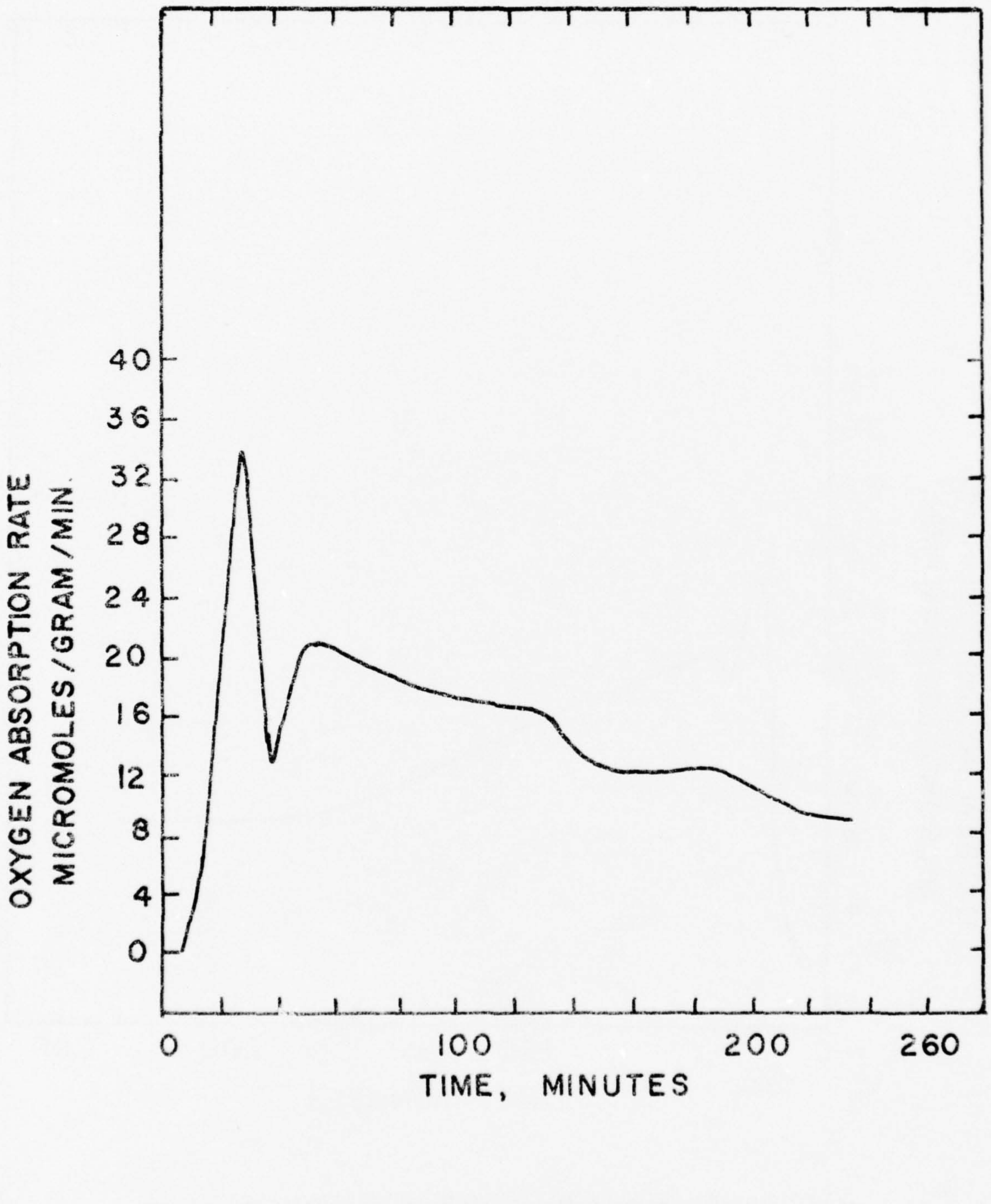

FIGURE 32. MLO-69-35. OXYGEN ABSORPTION RATES at 400 deg. F. 215 ml/min gas flow rate. RUN 3.

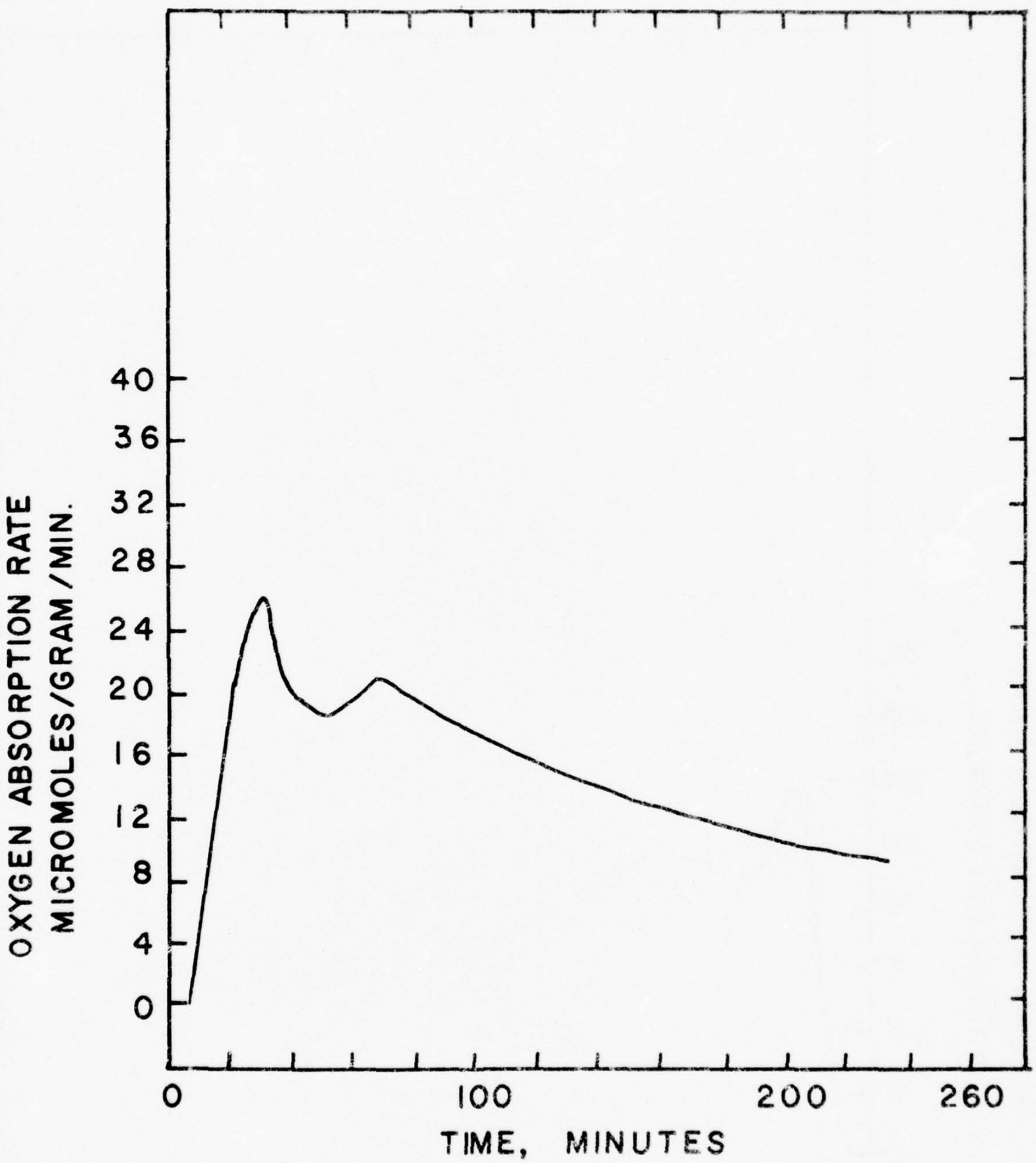

FIGURE 33. MLO-69-35. OXYGEN ABSORPTION RATES at 400 deg. F. 215 ml/min gas flow rate. RUN 4.

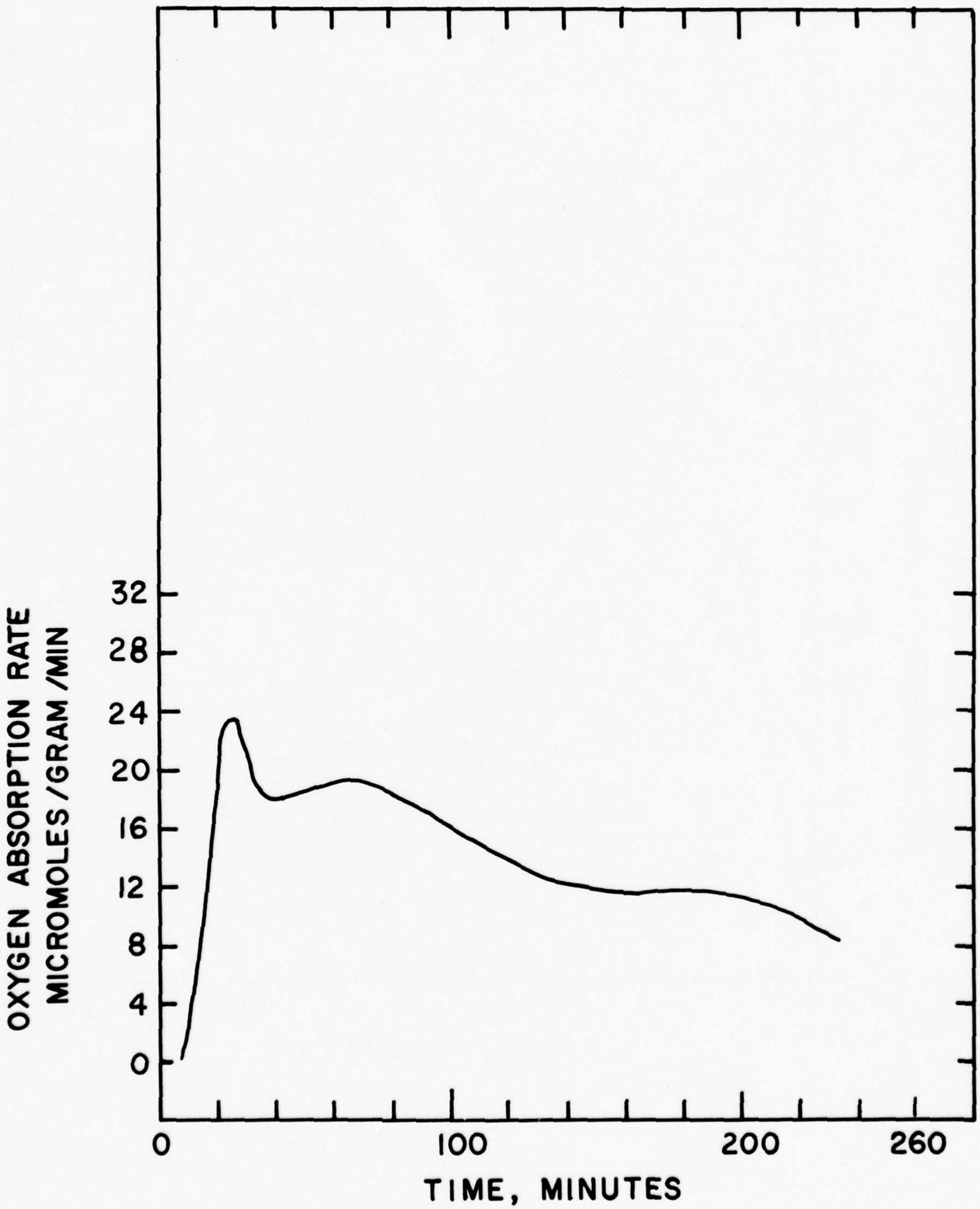

FIGURE 34. MLO-69-35. OXYGEN ABSORPTION RATES at 400 deg. F. 215 ml/min gas flow rate. Average of 4 Runs.

TABLE LIX

MLO-69-35

OIL PROPERTIES AFTER OXYGEN ABSORPTION TEST at 400 deg. F.

ORIGINAL OIL

Acid No., mg.KOH/gram	0.07
Viscosity @ 100 deg. F., cs.	24.64

After Oxidation Absorption Test, 400 deg. F.
240 min, 215 ml/min. flow rate

Run No.	Acid No., mg.KOH/gram	Viscosity @ 100 deg. F., cs.	Viscosity Increase, cs.	Viscosity Increase, %
1	22.6	152.25	127.61	518
2	20.77	134.07	109.43	444
3	20.61	167.73	143.09	581
4	21.58	178.19	153.55	623
4 Run Average	21.39	158.06	133.42	542

TABLE LX

MLO-69-35 + 1% (5-10-10) + 1% Pana

OXYGEN ABSORPTION
at 450 deg. F., 215 ml/min. gas flow rate

Time, minutes (cumulative)	Total Oxygen Absorption millimole/gram						
	Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-
20	-	0.001	-	-	0.001	0.00	0.00
25	-	0.002	-	0.02	0.01	0.01	0.01
30	-	0.02	-	0.03	0.02	0.01	0.005
45	0.003	0.05	0.01	0.04	0.03	0.02	0.02
60	0.01	0.10	0.02	0.06	0.05	0.04	0.03
75	0.02	0.12	0.09	0.06	0.07	0.04	0.03
90	0.05	0.18	0.11	0.06	0.10	0.06	0.04
105	0.16	0.21	0.14	0.11	0.16	0.04	0.03
120	-	0.27	0.18	0.13	0.19	0.07	0.05
135	0.18	0.42	0.19	0.13	0.23	0.13	0.09
150	0.18	0.63	0.54	0.20	0.39	0.23	0.16
165	0.52	1.09	0.88	0.20	0.67	0.39	0.26
180	0.72	1.37	1.24	0.55	0.97	0.40	0.27
195	0.95	1.62	1.56	0.91	1.26	0.38	0.26
210	1.00	1.90	1.84	1.21	1.49	0.45	0.30
225	1.33	2.17	2.08	1.57	1.79	0.40	0.27
240	1.59	2.41	2.32	1.84	2.04	0.39	0.26

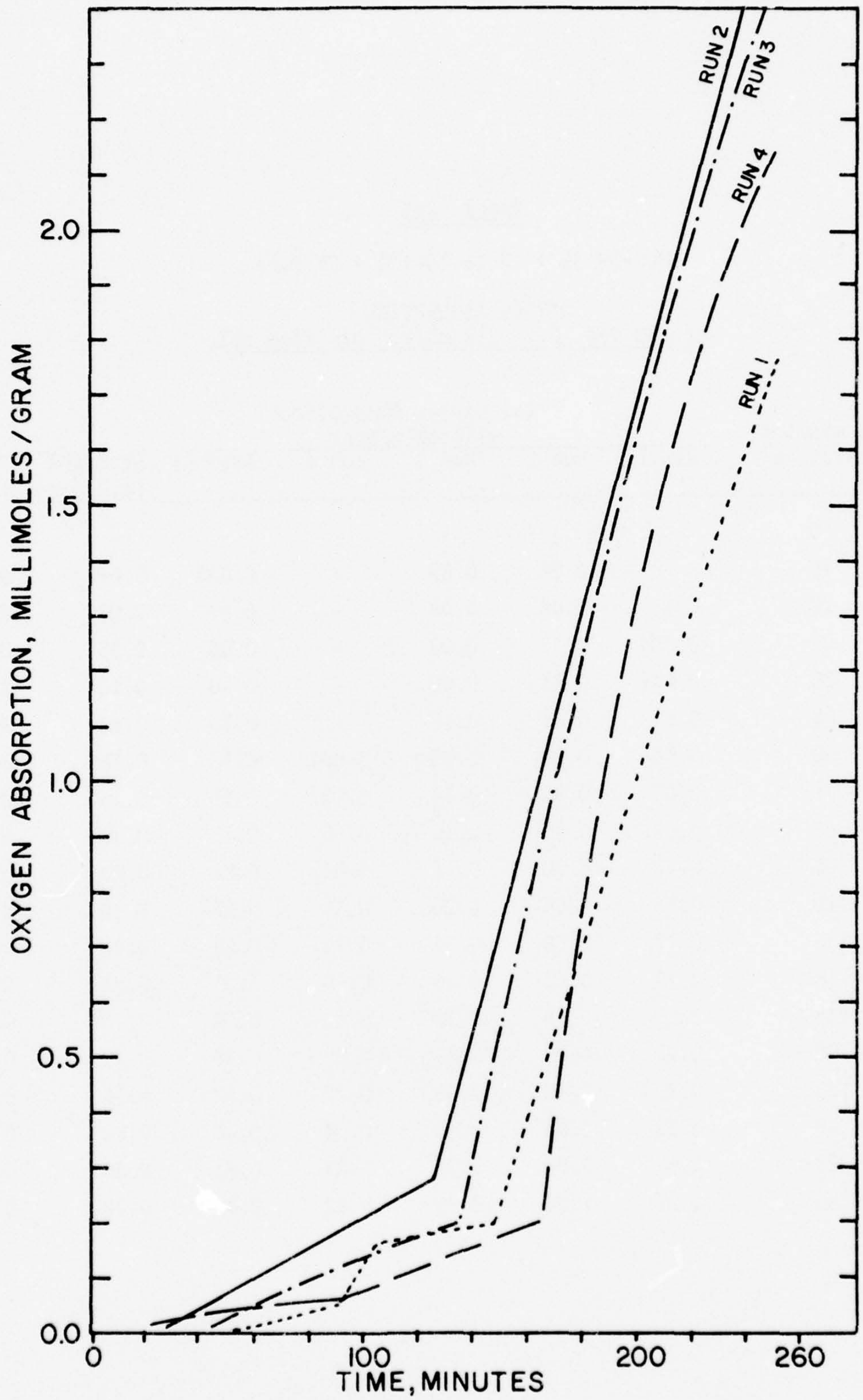

FIGURE 35. MLO-69-35 + 1% (5-10-10) + 1% Pana
OXYGEN ABSORPTION
at 450 deg. F. 215 ml/min gas flow rate.

TABLE LXI

MLO-69-35 + 1% (5-10-10) + 2% Pana

OXYGEN ABSORPTION
at 450 deg. F., 215 ml/min gas flow rate

Time, minutes (cumulative)	Total Oxygen Absorption millimole/gram						
	Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0	-	-	-	-	-	-	-
15	-	0.04	0.03	-	0.035	0.01	0.01
20	-	0.08	0.06	-	0.07	0.01	0.09
25	0.004	0.11	0.08	-	0.06	0.05	0.04
30	0.005	0.21	0.09	-	0.10	0.10	0.07
45	0.01	0.25	0.12	-	0.13	0.12	0.08
60	0.04	0.30	0.13	0.001	0.12	0.13	0.09
75	0.06	0.36	0.15	0.03	0.15	0.15	0.10
90	0.07	0.44	0.16	0.06	0.18	0.18	0.12
105	0.10	0.50	0.18	0.08	0.22	0.20	0.13
120	0.15	0.54	0.20	0.10	0.25	0.20	0.13
135	0.17	0.58	0.24	0.14	0.28	0.20	0.14
150	0.19	0.62	0.26	0.16	0.31	0.21	0.14
165	0.20	0.68	0.28	0.18	0.34	0.23	0.16
180	0.23	0.70	0.31	0.20	0.36	0.23	0.16
195	0.30	0.80	0.34	0.22	0.42	0.26	0.18
210	0.32	0.85	0.34	0.24	0.44	0.28	0.19
225	0.52	0.94	0.36	0.33	0.61	0.26	0.17
240	0.72	1.05	0.39	0.52	0.67	0.29	0.19

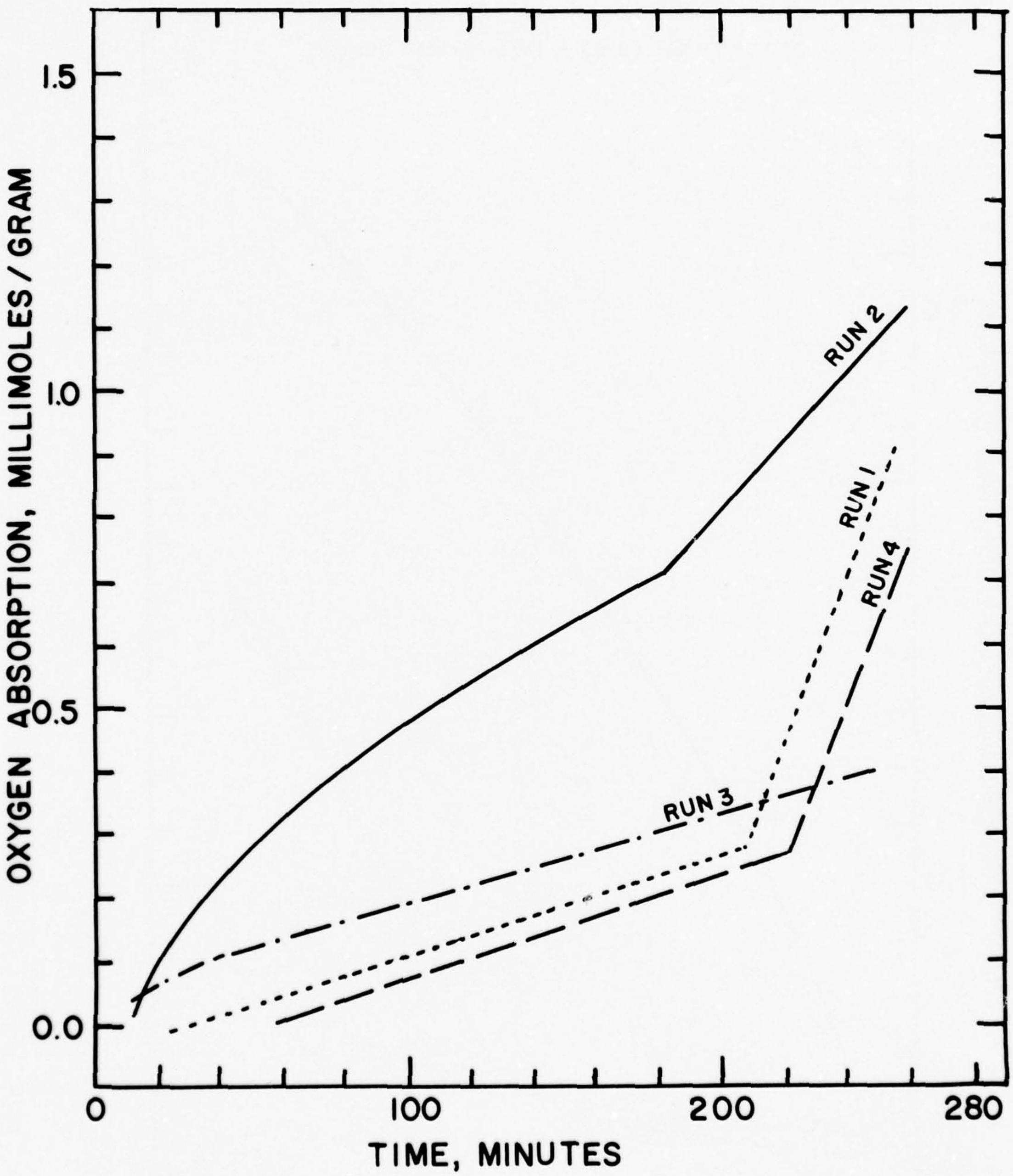

FIGURE 36. MLO-69-35 + 1% (5-10-10) + 2% Pana
OXYGEN ABSORPTION
at 450 deg. F. 215 ml/min gas flow rate.

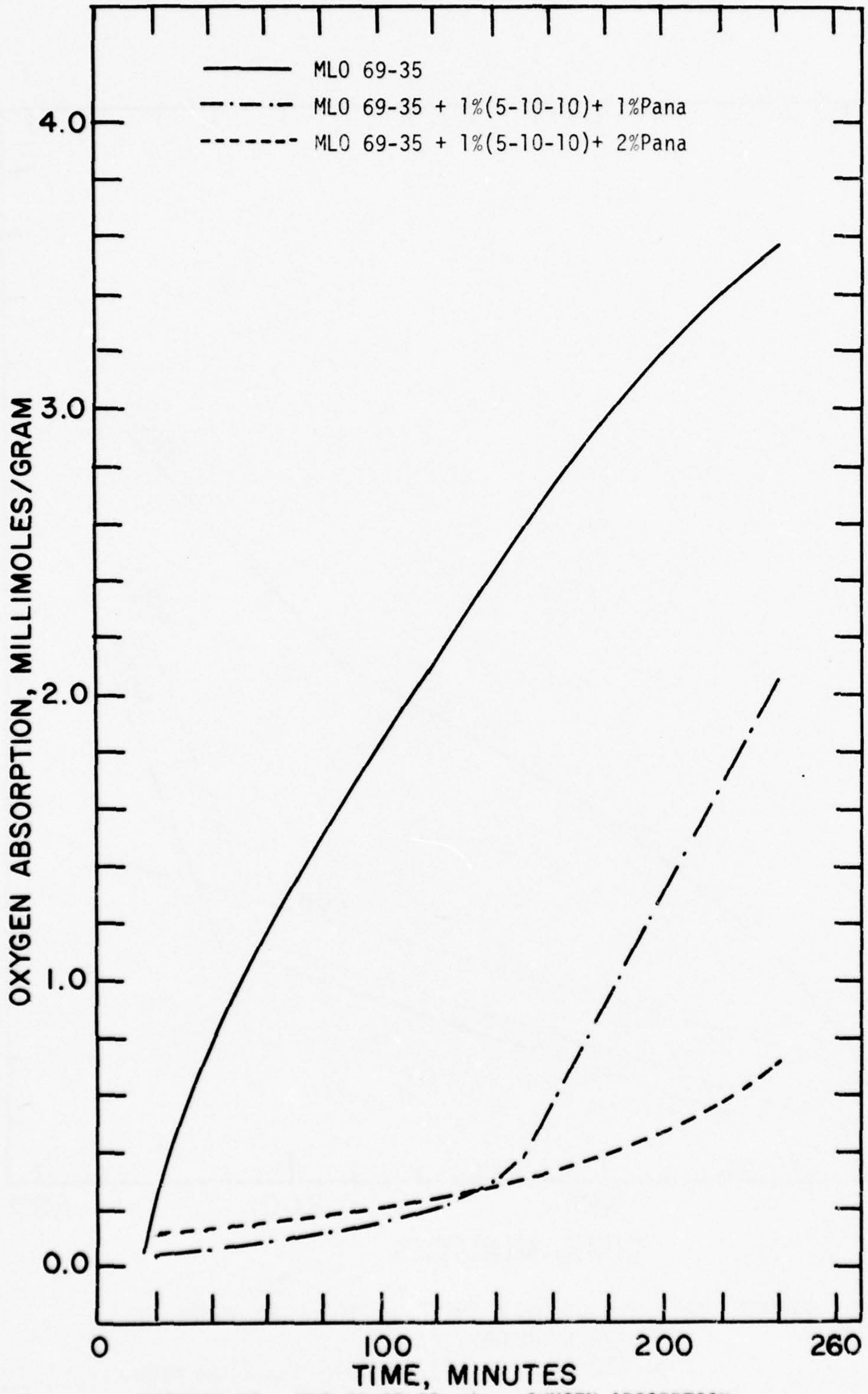

FIGURE 37. MLO-69-35 Blends. OXYGEN ABSORPTION at 450 deg. F. 215 ml/min gas flow rate. Average Values, 4 Determinations

TABLE LXII

MLO-69-35 + 1% (5-10-10) + 1% Pana

OXYGEN ABSORPTION RATE
at 450 deg. F., 215 ml/min gas flow rate

Time Interval, Minutes	Oxygen Absorption Rate micromoles/gram/min. Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0 - 15	-	-	-	-	-	-	-
15 - 20	-	0.16	-	-	0.16	-	-
20 - 25	-	0.16	-	3.77	1.96	2.55	1.72
25 - 30	-	4.11	-	1.77	2.94	1.65	1.12
30 - 45	0.20	1.80	0.61	0.51	0.78	0.70	0.47
45 - 60	0.36	3.30	0.80	1.28	1.44	1.30	0.88
60 - 75	0.67	1.53	4.78	0.54	1.88	1.98	1.34
75 - 90	2.40	3.60	1.41	0.16	1.89	1.46	0.99
90 - 105	6.89	2.18	1.43	2.76	3.32	2.44	1.65
105 - 120	-	3.81	2.68	1.55	2.68	1.13	0.76
120 - 135	1.14	9.99	0.98	0.29	3.10	4.61	3.11
135 - 150	0.53	14.4	23.3	4.36	10.65	10.26	6.92
150 - 165	22.3	30.4	22.4	0.08	18.80	13.0	8.80
165 - 180	14.1	18.9	24.2	23.4	20.2	4.66	3.14
180 - 195	15.0	16.3	21.1	23.9	19.1	4.15	2.80
195 - 210	3.26	19.1	19.4	20.1	15.5	8.15	5.50
210 - 225	21.6	18.0	15.5	23.9	19.8	3.73	2.52
225 - 240	17.6	16.2	16.6	18.0	17.1	0.84	0.57

TABLE LXIII

MLO-69-35 + 1% (5-10-10) + 2% Pana

OXYGEN ABSORPTION RATE
at 450 deg. F., 215 ml/min gas flow rate

Time Interval, Minutes	Oxygen Absorption Rate micromoles/gram/min. Run 1	Run 2	Run 3	Run 4	Average	Standard Deviation	Probable Error
0 - 15	-	8.56	6.25	-	7.38	1.59	1.01
15 - 20	-	6.67	4.94	-	5.80	1.22	0.82
20 - 25	0.89	7.58	4.11	-	4.19	3.35	2.20
25 - 30	0.08	19.4	3.37	-	7.62	10.30	6.97
30 - 45	0.35	8.40	1.89	-	3.55	4.27	2.88
45 - 60	2.00	8.65	0.82	0.08	2.89	3.92	2.65
60 - 75	1.38	13.4	0.99	1.72	4.37	6.03	4.06
75 - 90	0.81	16.1	0.74	2.13	4.94	7.46	5.03
90 - 105	1.76	13.8	1.15	1.72	4.61	6.13	4.14
105 - 120	3.30	8.40	1.78	1.31	3.70	3.25	2.19
120 - 135	1.68	7.99	2.58	2.21	3.62	2.94	1.98
135 - 150	1.16	9.06	1.43	1.42	3.27	3.86	2.61
150 - 165	0.57	11.90	1.26	1.58	3.83	5.40	3.64
165 - 180	1.70	3.21	1.65	1.34	1.98	0.84	0.57
180 - 195	5.11	19.8	1.86	1.45	7.06	8.65	5.84
195 - 210	0.89	10.4	0.58	1.31	3.30	4.75	3.20
210 - 225	13.6	17.9	1.32	5.76	9.64	7.49	5.05
225 - 240	13.3	22.2	2.00	12.40	12.48	8.27	5.58

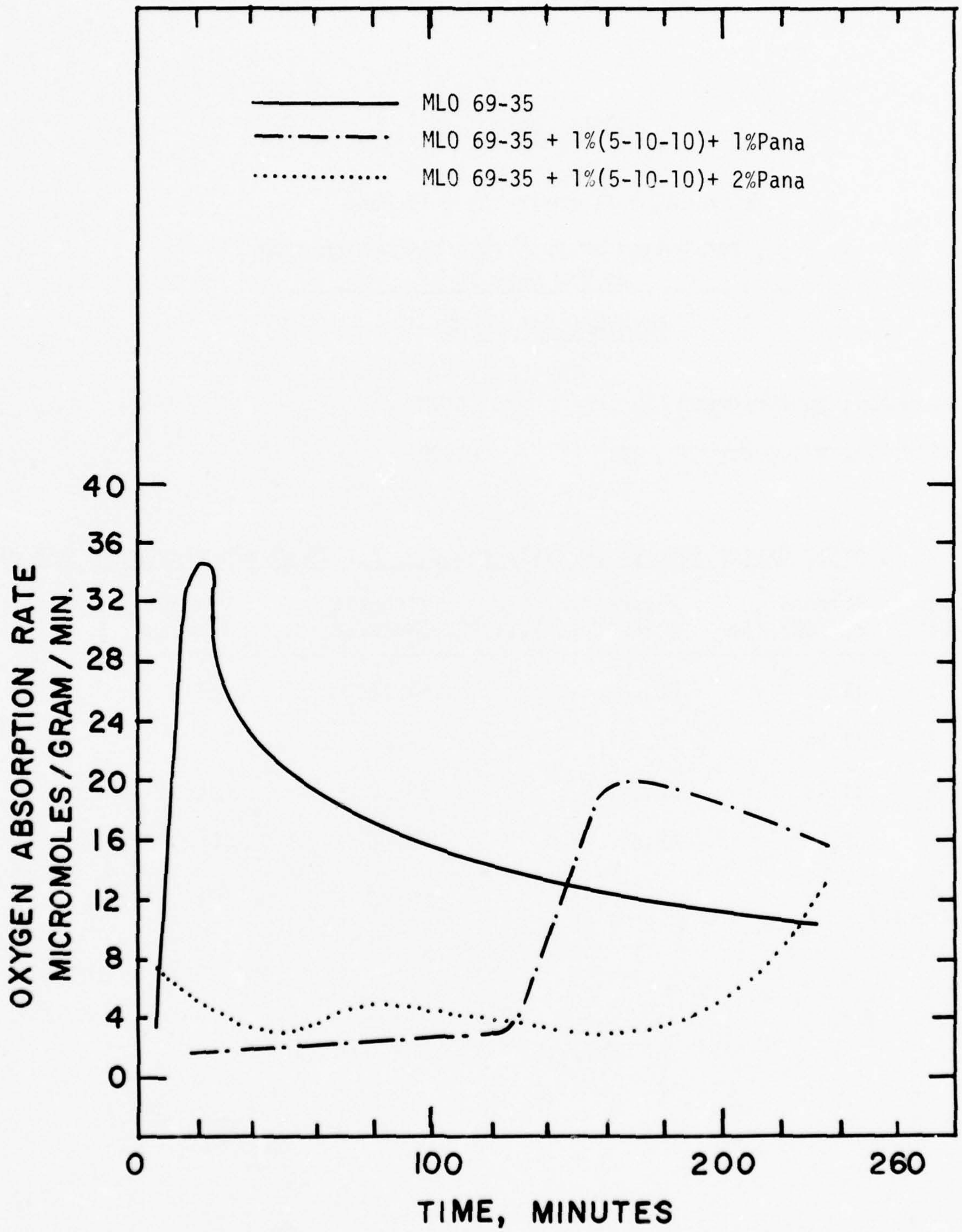

FIGURE 38. MLO-69-35 Blends. OXYGEN ABSORPTION RATES at 450 deg. F. 215 ml/min gas flow rate. Average, 4 Determinations.

TABLE LXIV

MLO-69-35 + 1% (5-10-10) + 1% Pana

OIL PROPERTIES AFTER OXYGEN ABSORPTION TESTS
at 450 deg. F.

ORIGINAL OIL BLEND

Acid No., mg KOH/gram	0.08
Viscosity @ 100 deg. F., cs.	24.90

After Oxygen Absorption Test, 450 deg. F.,215 ml/min flow rate, 240 min.

Run No.	Acid No., mg KOH/gram	Viscosity @ 100 deg. F., cs.	Viscosity Increase, cs.	Viscosity Increase, %
1	11.61	66.04	41.14	165
2	17.68	80.11	55.21	222
3	11.90	88.20	63.30	254
4	9.45	65.61	40.71	163
4 Run Average	12.66	74.99	50.09	201

TABLE LXV

MLO-69-35 + 1% (5-10-10) + 2% Pana

OIL PROPERTIES AFTER OXYGEN ABSORPTION TESTS
at 450 deg. F.

ORIGINAL OIL BLEND

Acid No., mg.KOH/gram	0.09
Viscosity @ 100 deg. F., cs.	26.31

After Oxygen Absorption Test, 450 deg. F., 215 ml/min flow rate

Run No.	Acid No., mg.KOH/gram	Viscosity @ 100 deg. F., cs.	Viscosity Increase, cs.	Viscosity Increase, %
1	3.37	35.42	9.11	34.6
2	4.73	41.49	15.63	59.4
3	0.72	29.12	2.81	10.7
4	2.75	32.55	6.24	23.7
4 Run Average	2.89	34.64	8.45	32.0

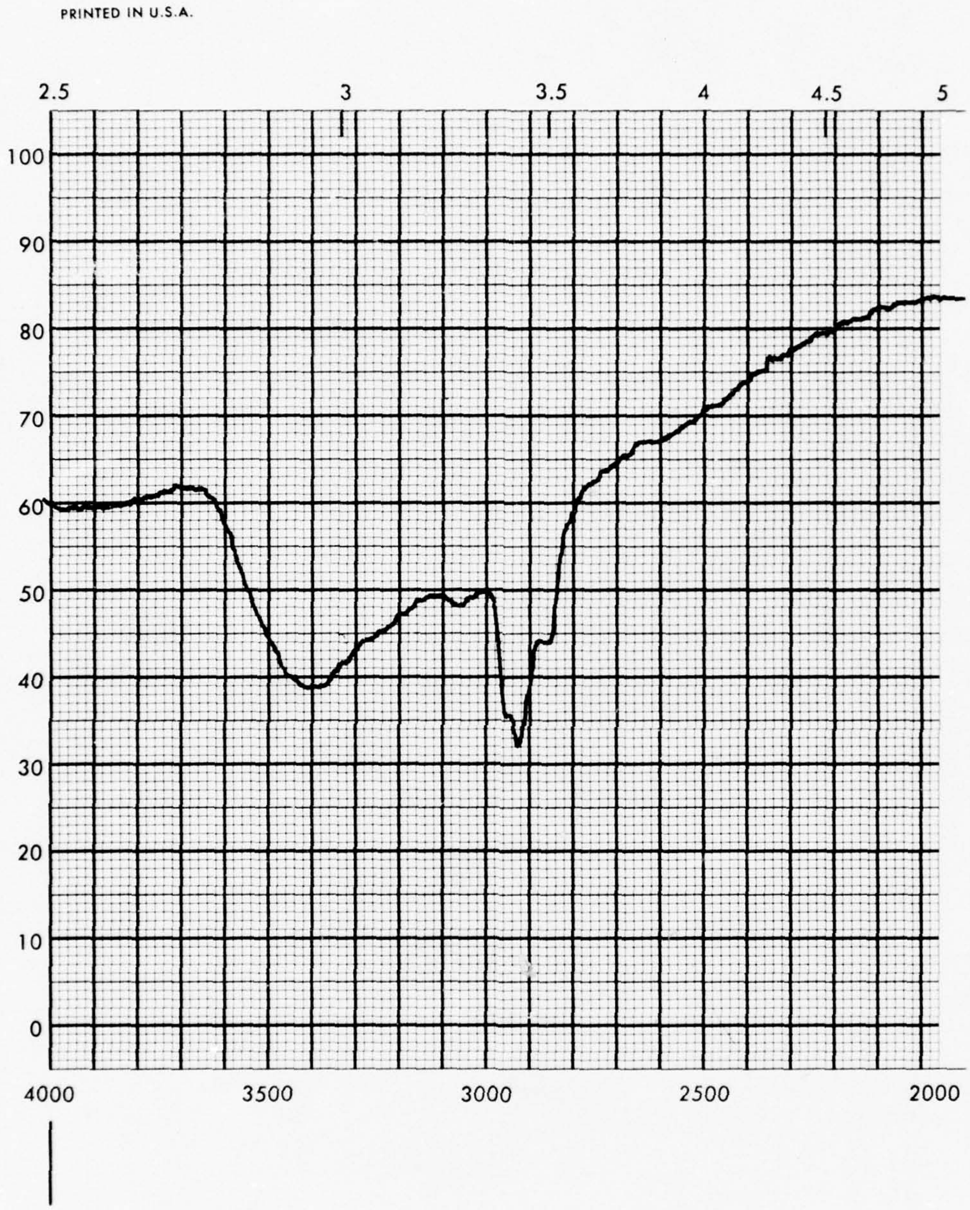

FIGURE 39. MLO-69-35 + 1% (5-10-10) + 2% Pana.
HEXANE INSOLUBLE RESIDUE FROM TUBE WALL.
RUN 2. 4000-2000 cm^{-1}

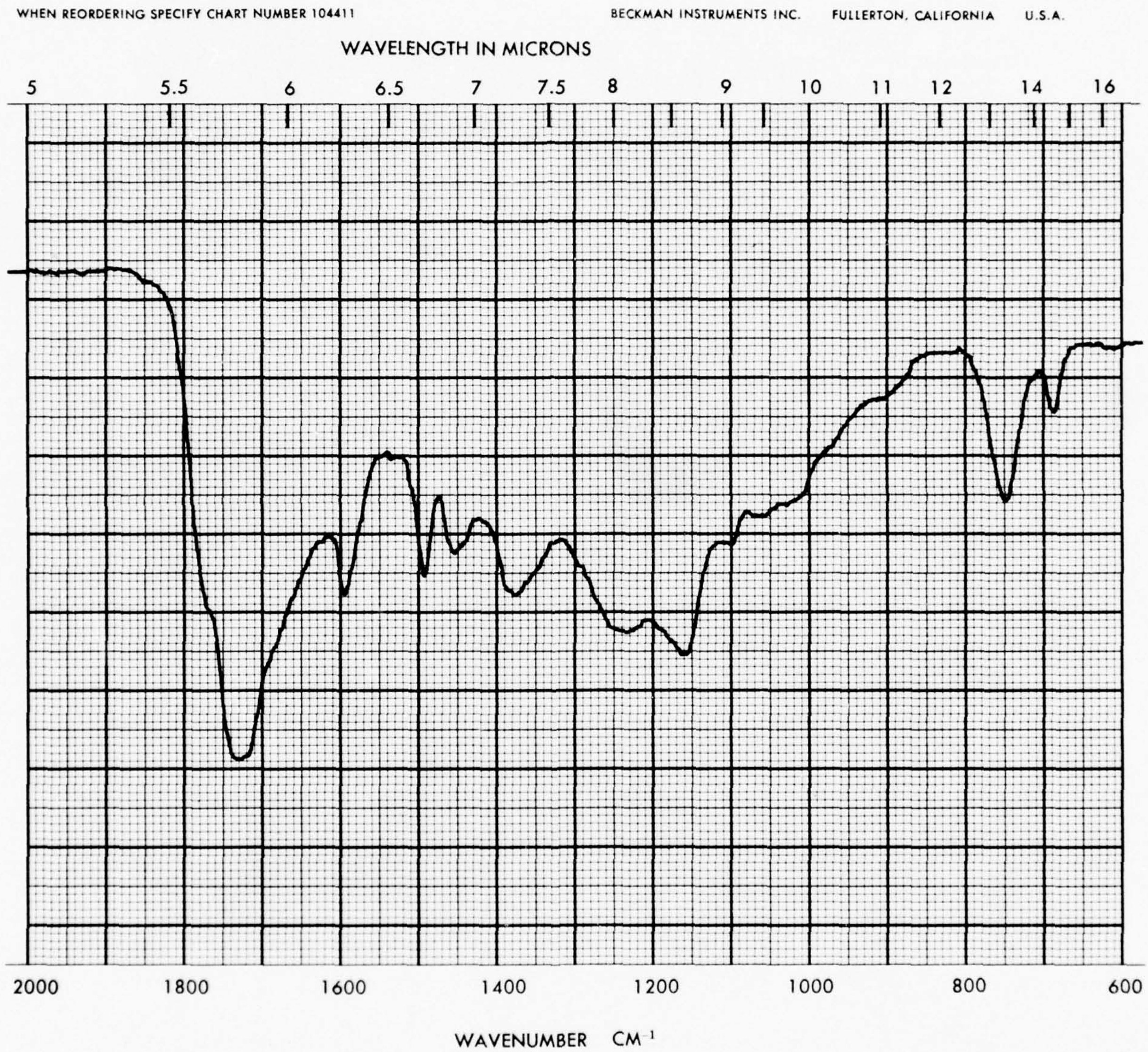

FIGURE 40. MLO-69-35 + 1% (5-10-10) + 2% Pana.
HEXANE INSOLUBLE RESIDUE FROM TUBE WALL
RUN 2. 2000-600 cm^{-1}

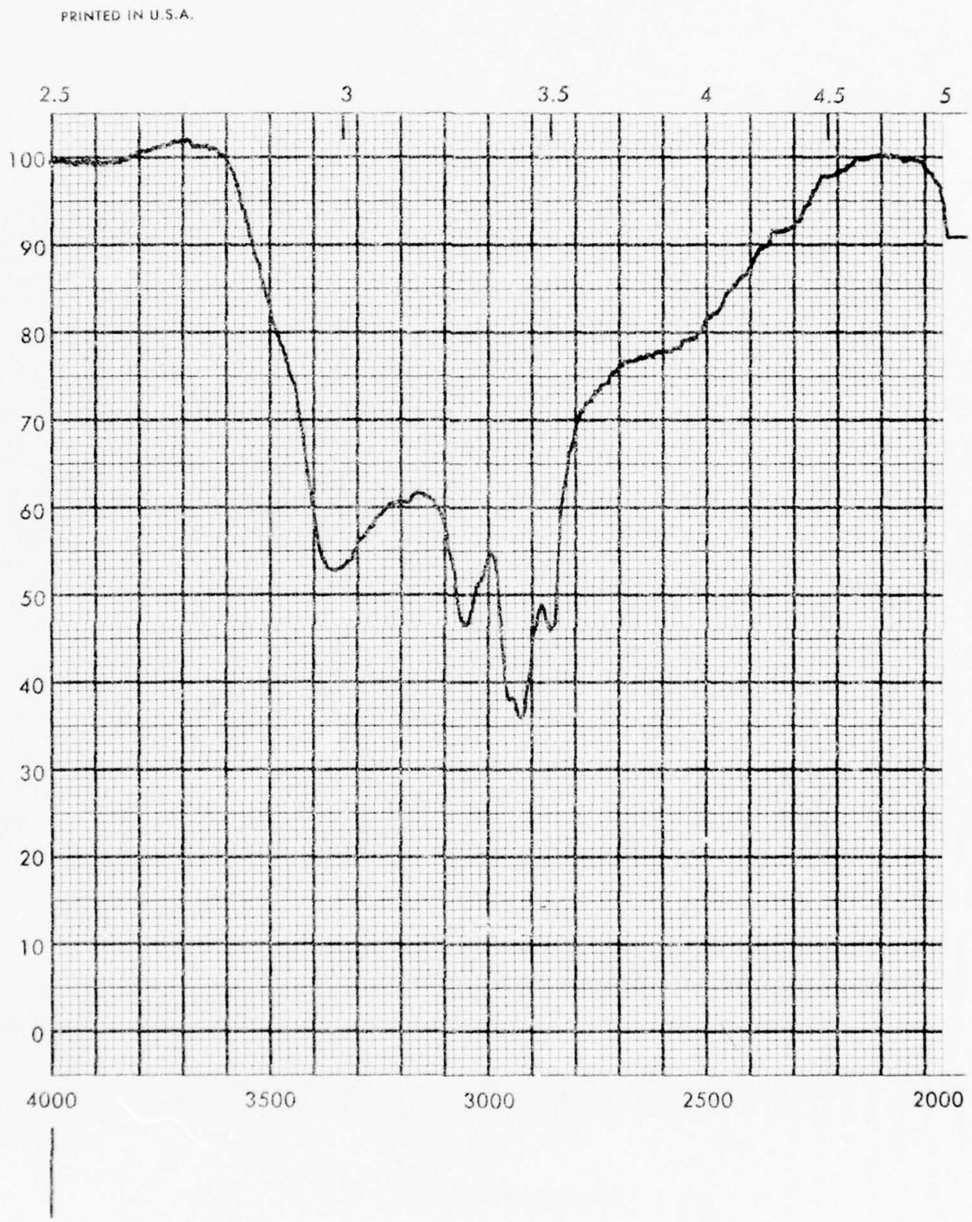

FIGURE 41. MLO-69-35 + 1% (5-10-10) + 2% Pana.
HEXANE INSOLUBLE RESIDUE FROM TUBE WALL.
RUN 3. 4000-2000 cm^{-1}

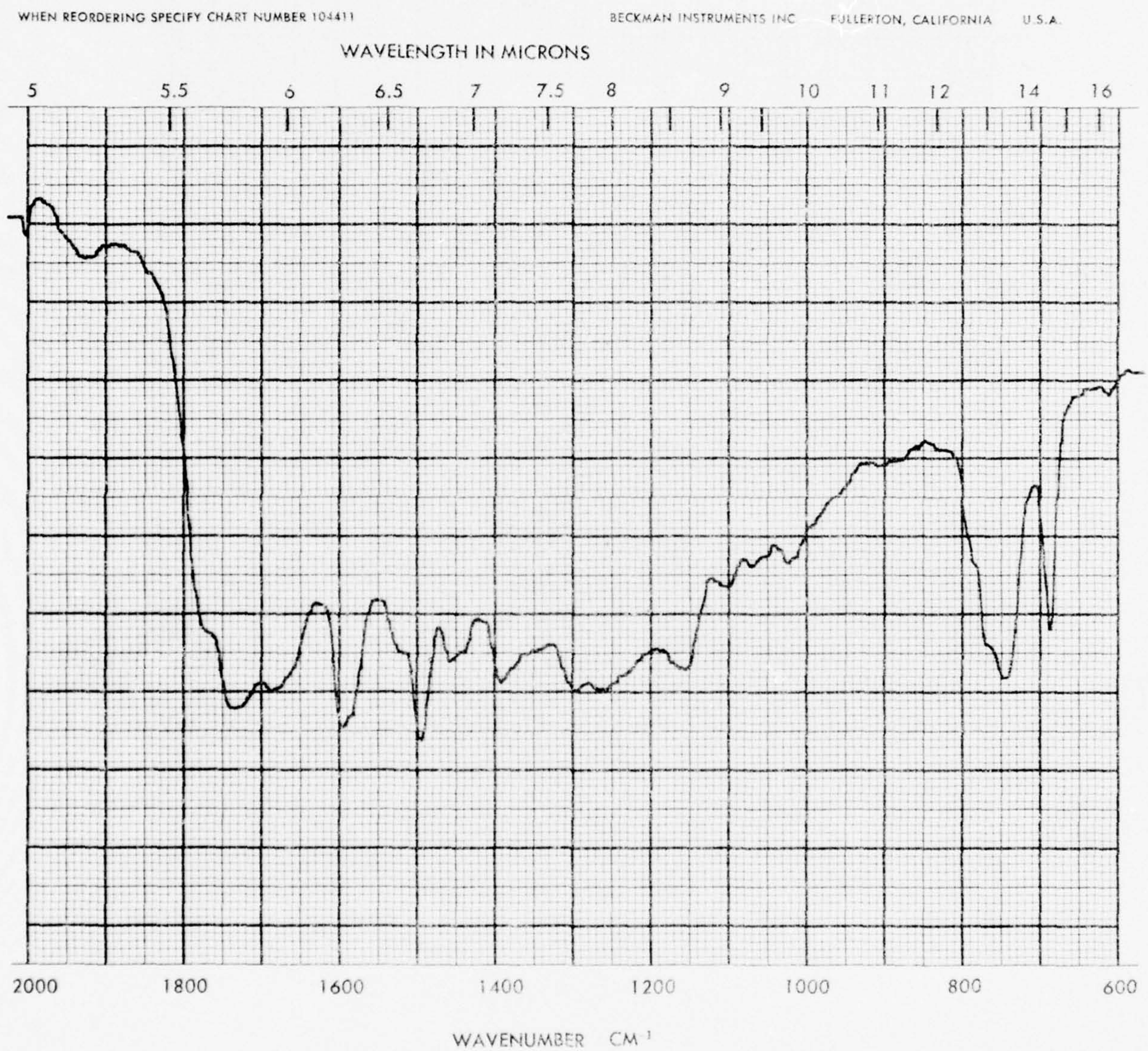

FIGURE 42. MLO-69-35 + 1% (5-10-10) + 2% Pana.
HEXANE INSOLUBLE RESIDUE FROM TUBE WALL.
RUN 3. 2000-600 cm^{-1}

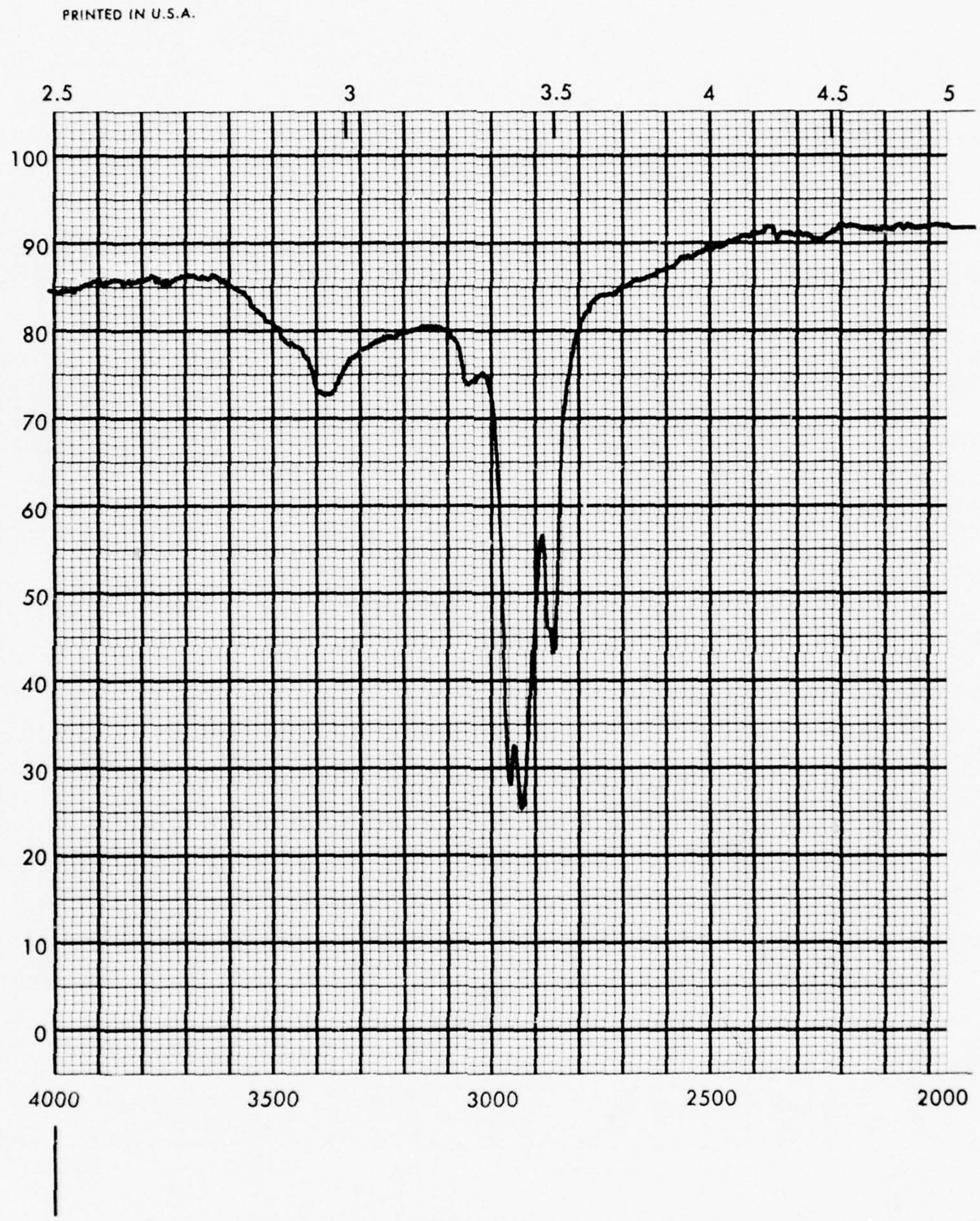

FIGURE 43. MLO-69-35 + 1% (5-10-10) + 2% Pana.
FROM COLD TRAP
RUN 3. 4000-2000 cm^{-1}

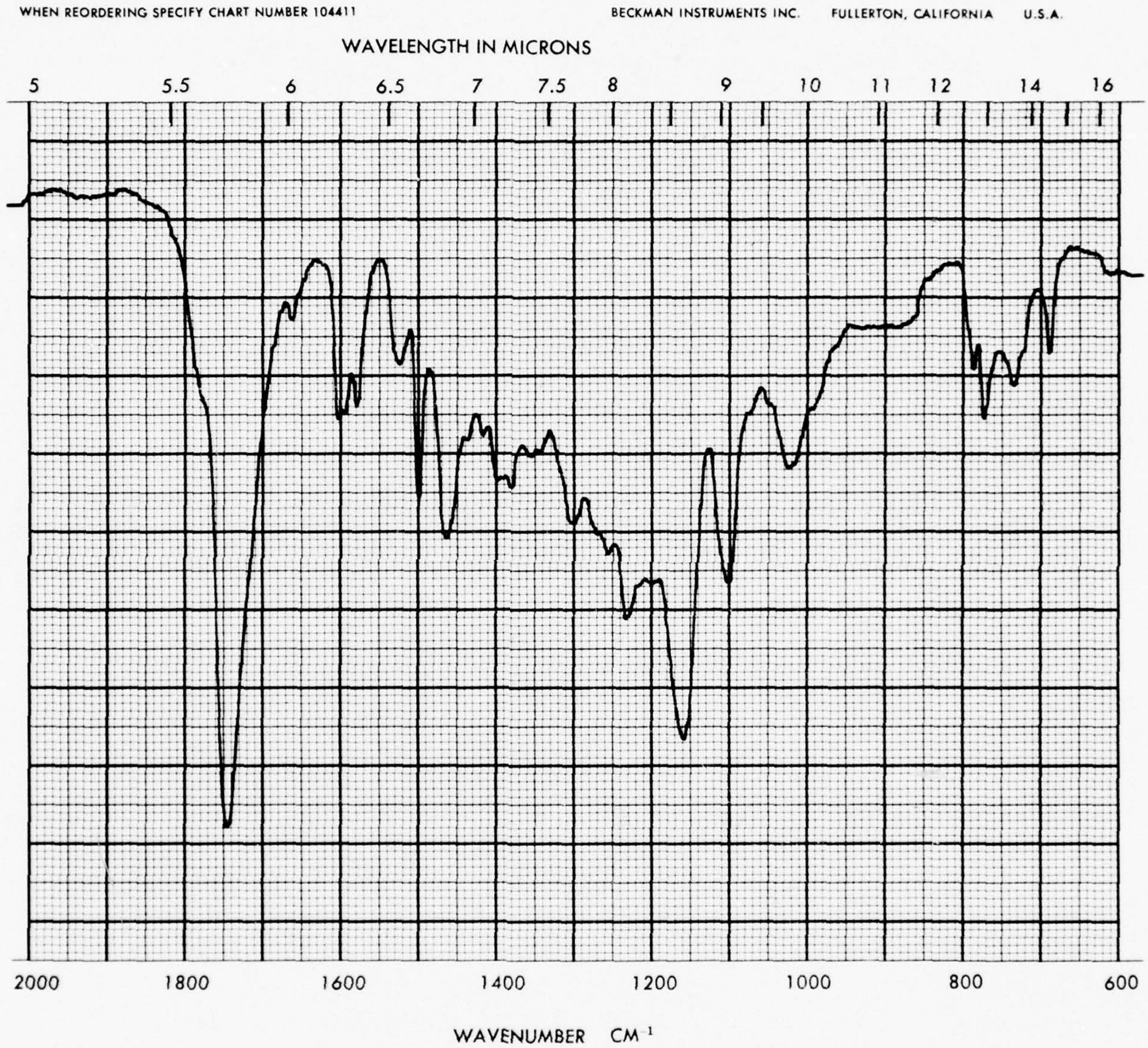

FIGURE 44. MLO-69-35 + 1% (5-10-10) + 2% Pana.
FROM COLD TRAP
RUN 3. 2000-600 cm^{-1}

TABLE LXVI

MLO-69-35 BLENDS

OIL PROPERTIES AFTER OXIDATION ABSORPTION TESTS,
240 min 215 ml/min gas flow rate

Temperature, Deg. F. & Sample	Acid No., mg.KOH/gram	Viscosity @ 100 deg. F., cs.	Viscosity Increase, cs.	Viscosity Increase, %
400 deg. F. MLO-69-35 4 Run Average	21.39	158.06	133.42	542
450 deg. F. MLO-69-35 4 Run Average	30.50	255.18	230.39	935
450 deg. F. MLO-69-35 + 1%(5-10-10) + 1% Pana 4 Run Average	12.66	74.99	50.09	201
450 deg. F. MLO-69-35 + 1%(5-10-10) +2% Pana 4 Run Average	2.89	34.64	8.45	32

TABLE LXVII

MLO-69-35 BLENDS

INDUCTION PERIODS, MINUTES

MLO-69-35	
Run 1	15
Run 2	14.5
Run 3	15
Run 4	15
4 Run Average	15
MLO-69-35 + 1% (5-10-10) + 1% Pana	
Run 1	90 (minor), 146 (major)
Run 2	125
Run 3	135
Run 4	90 (minor), 165 (major)
4 Run Average	143
MLO-69-35 + 1% (5-10-10) + 2% Pana	
Run 1	207
Run 2	181
Run 3	none (over 240)
Run 4	221
4 Run Average	210

TABLE LXVIII

MLO-71-6 OXYGEN ABSORPTION TESTS
at 600 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Changes, ml. Run 1	Run 2
0	0	0
15	0	0
20	0	0
25	0	-0.1
30	0	-0.3
45	-0.1	0
60	-0.1	0
75	0	+0.1
90	+0.1	-0.2
105	+0.2	0
120	+0.2	+0.1
135	+0.5	0
150	-0.4	0
165	+0.2	-0.1
180	+0.2	-0.1
195	+0.1	+0.1
210	-0.1	0
225	+0.1	+0.1
240	-0.3	-0.3
Net Change	+0.6	-0.7
Weight Sample, grams	18.9886	18.8825
Trap condensate, grams	0.17	0.19
Oxidized Oil Properties		
Viscosity @ 100 deg. F. cs	338.56	331.07
% Increase	18.11	15.50
Acid No., mg KOH/gram	0.01	0.01

TABLE LXIX

MLO-71-6 OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Changes, ml. (740 torr, 77 deg. F.) Run 1	Run 2
0	0	0
15	+ 8.6	+19.5
20	+11.0	0
25	+ 1.0	0
30	+ 2.0	+12.2
45	+ 4.3	+ 9.1
60	+ 4.6	+15.4
75	+ 3.4	+10.1
90	+ 1.4	+ 8.5
105	+ 3.6	+ 8.3
120	+ 2.1	+ 4.2
135	+ 4.0	+ 3.0
150	+ 4.7	+ 5.6
165	0	+ 1.7
180	- 2.2	+ 2.4
195	- 0.1	0
210	- 1.6	- 3.6
225	- 4.0	+ 3.6
240	0	+ 2.2
Net Change	+42.8	+102.2
Weight Sample, grams	19.0231	19.0787
Weight Trap condensate, grams	0.27	0.20
Acid No. of condensate	10.18	8.57
Oxidized Oil Properties		
Viscosity @ 100 deg. F., cs.	331.2	313.0
% Increase	15.54	9.19
Acid No., mg.KOH/gram	0.01	0.01

TABLE LXX

MLO-71-6 OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes	Volume Changes, ml. (745 torr, 78.5 deg. F.)	
Cumulative	Run 3	Run 4
0	0	0
15	+10.7	_8.5
20	+6.6	+1.4
25	0	0
30	0	0
45	-2.7	0
60	-6.8	+3.2
75	-0.2	+1.5
90	-7.2	+1.0
105	-5.2	+3.4
120	-1.9	+0.1
135	-4.4	0
150	-2.3	0
165	-2.8	0
180	-2.0	0
195	-2.3	-4.3
210	0	-0.1
225	-2.2	0
240	-0.1	-1
Net Change	-22.8	+13.7

TABLE LXX CONTINUED:

MLO-71-6 OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

	Run 3	Run 4
Weight Sample, grams	18.0535	19.2236
Weight Trap condensate, grams		
Ambient	0.5237	0.3607
Cold	0.1925	0.1602
Acid No. of condensate, mg.KOH/gram		
Ambient Trap	2.43	2.71
Cold Trap	2.67	2.72
Oxidized Oil Properties		
Viscosity @ 100 deg. F., cs.	345.0	333.5
% Increase	20.3	16.3
Acid No., mg.KOH/gram	0.01	0.01

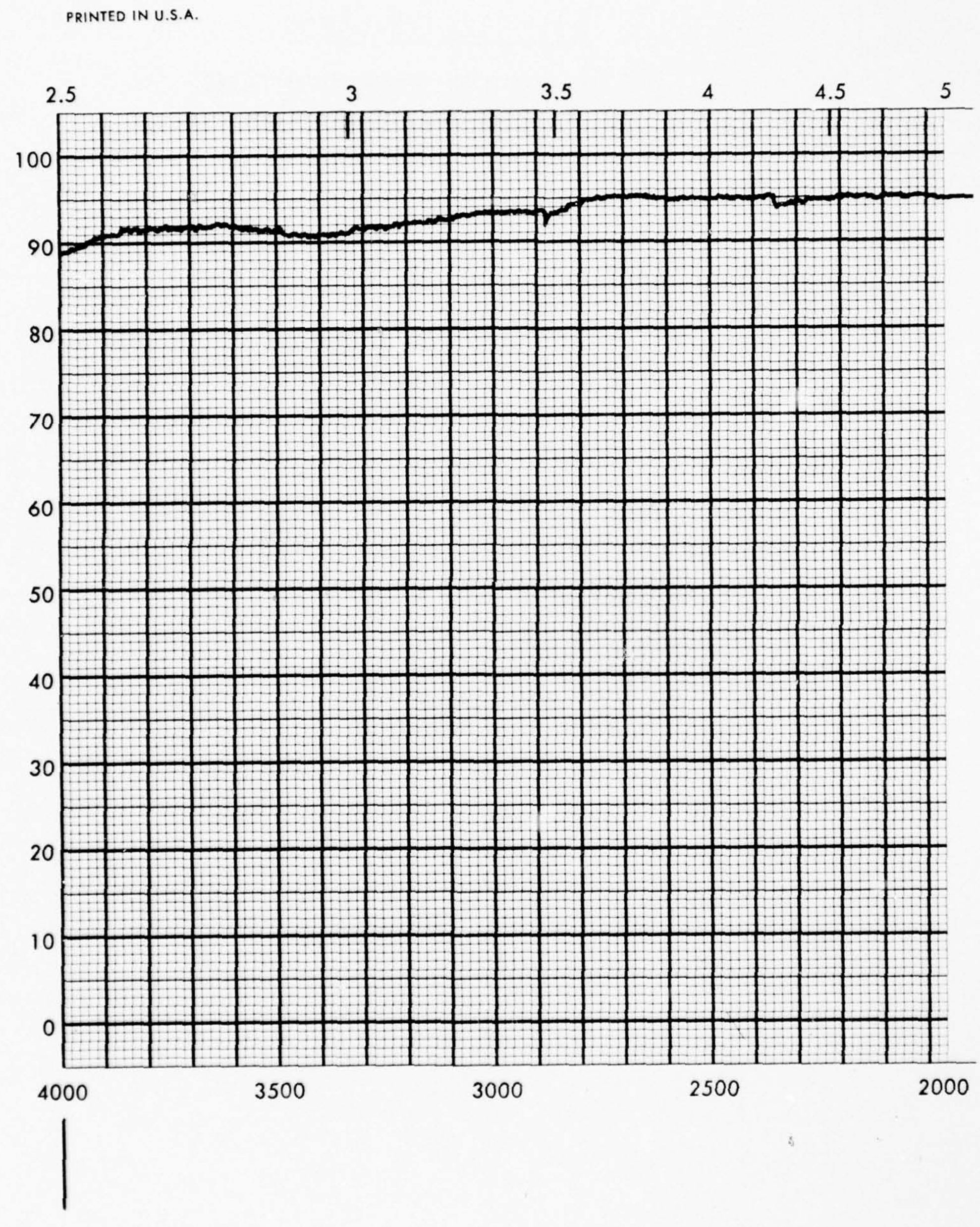

FIGURE 45. MLO-71-6 AS RECEIVED 4000-2000 cm^{-1}

FIGURE 46. MLO-71-6 AS RECEIVED 2000-600 cm^{-1}

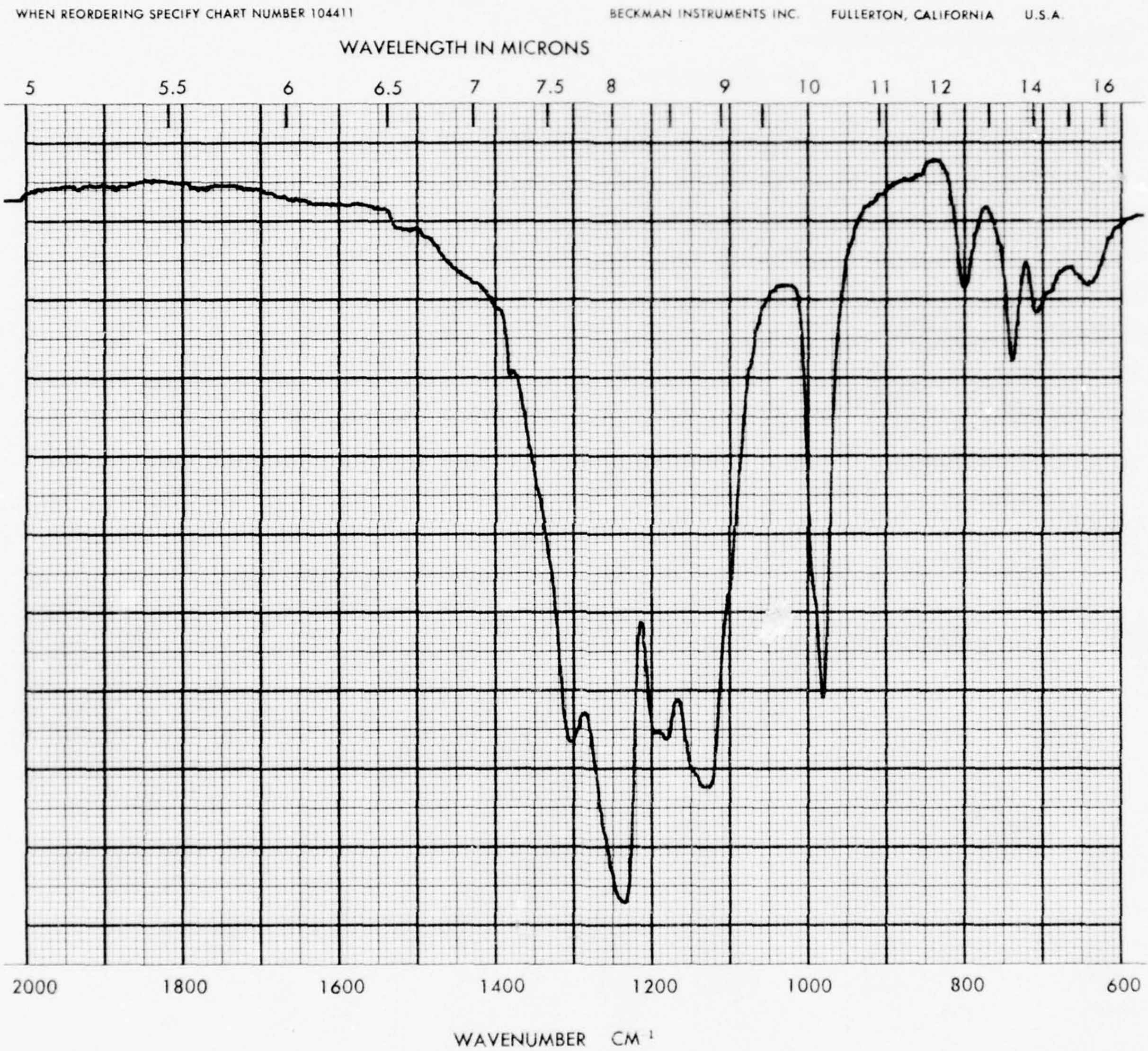

FIGURE 47. MLO-71-6 FROM AMBIENT TRAP. 2000-600 cm^{-1}

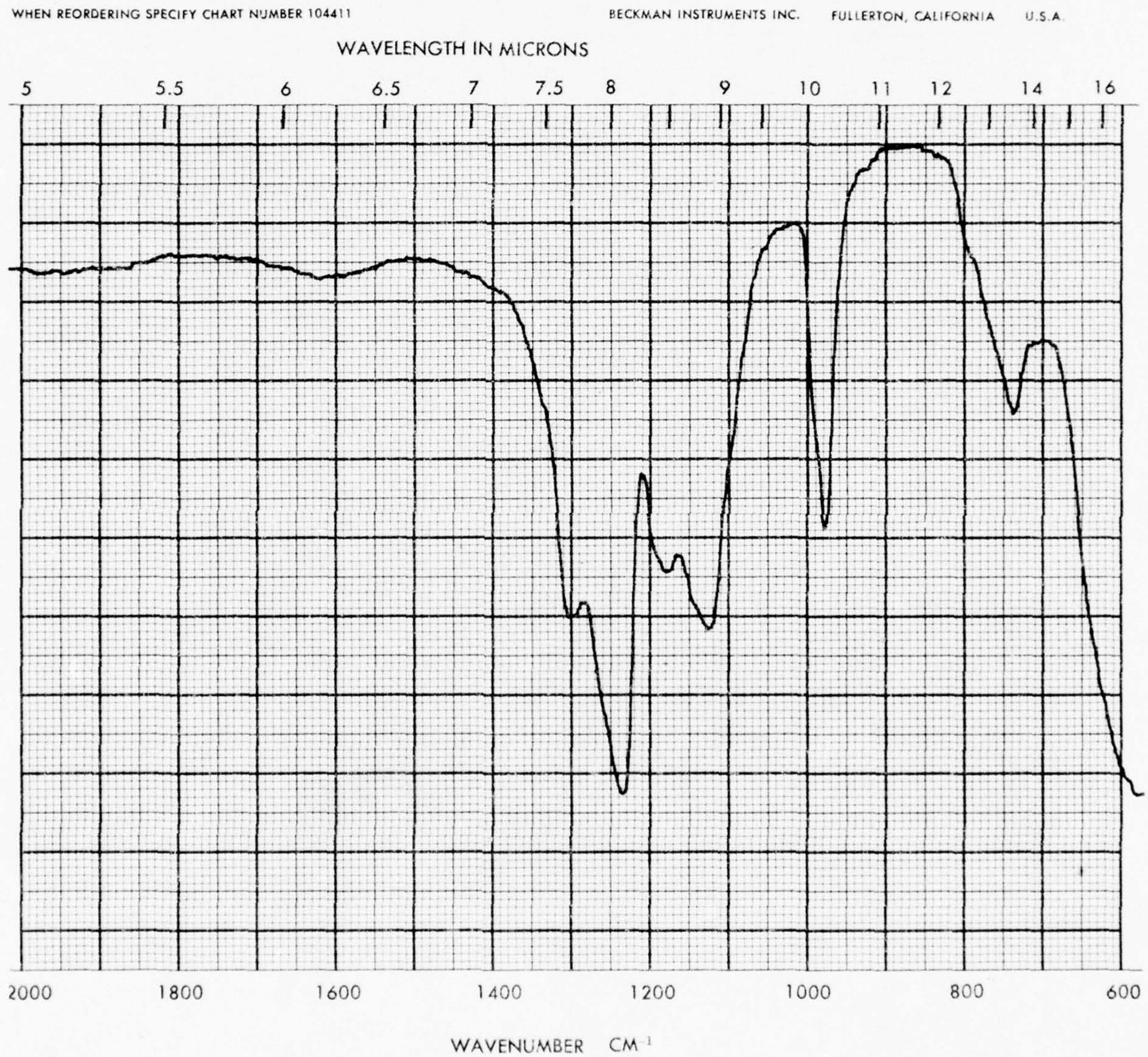

FIGURE 48. MLO-71-6 WHITE DEPOSIT IN REACTION TUBE, FREON INSOLUBLE 2000-600 cm^{-1}

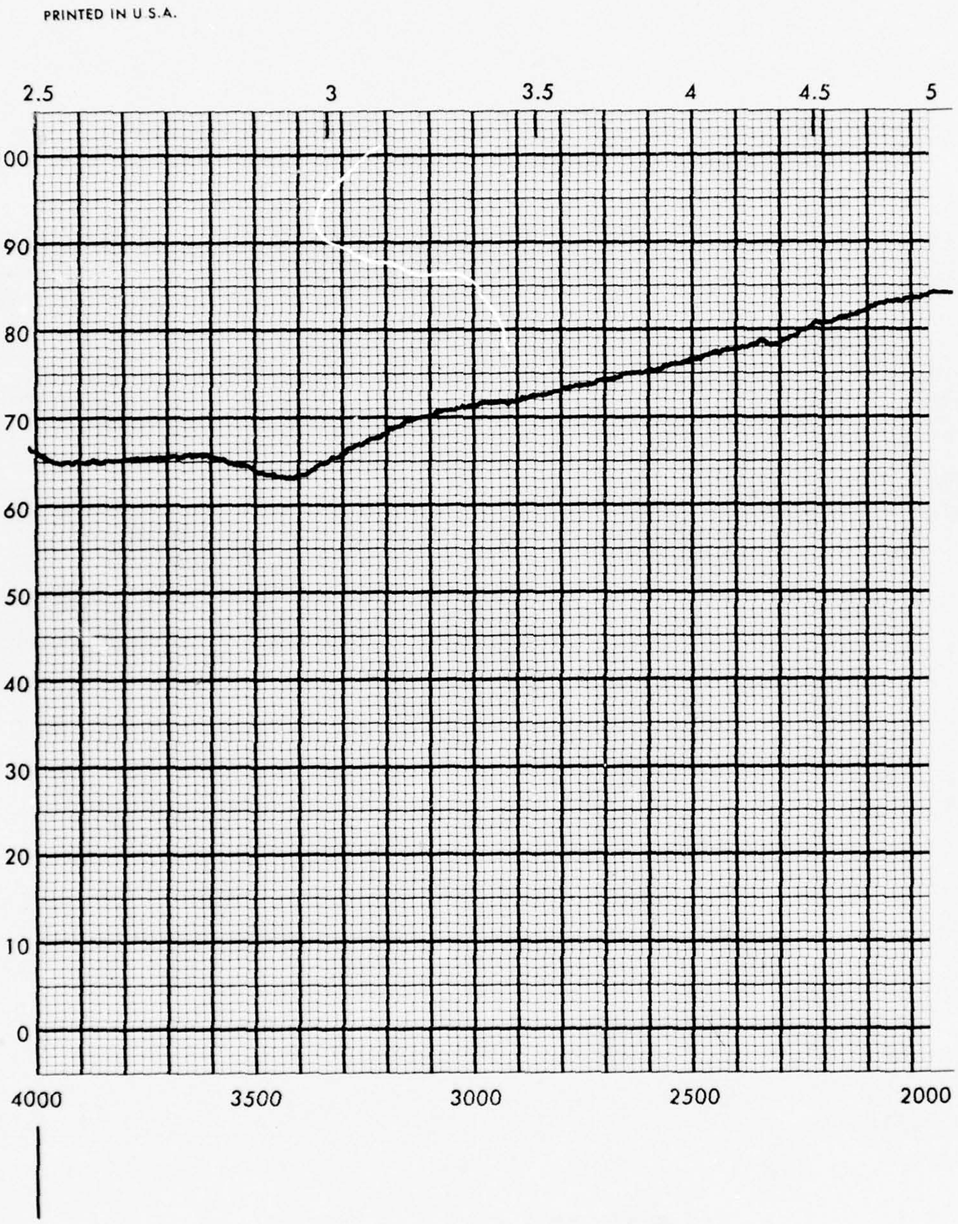

FIGURE 49. MLO-71-6 WHITE DEPOSIT IN OXYGEN DELIVERY TUBE
4000-2000 cm^{-1}

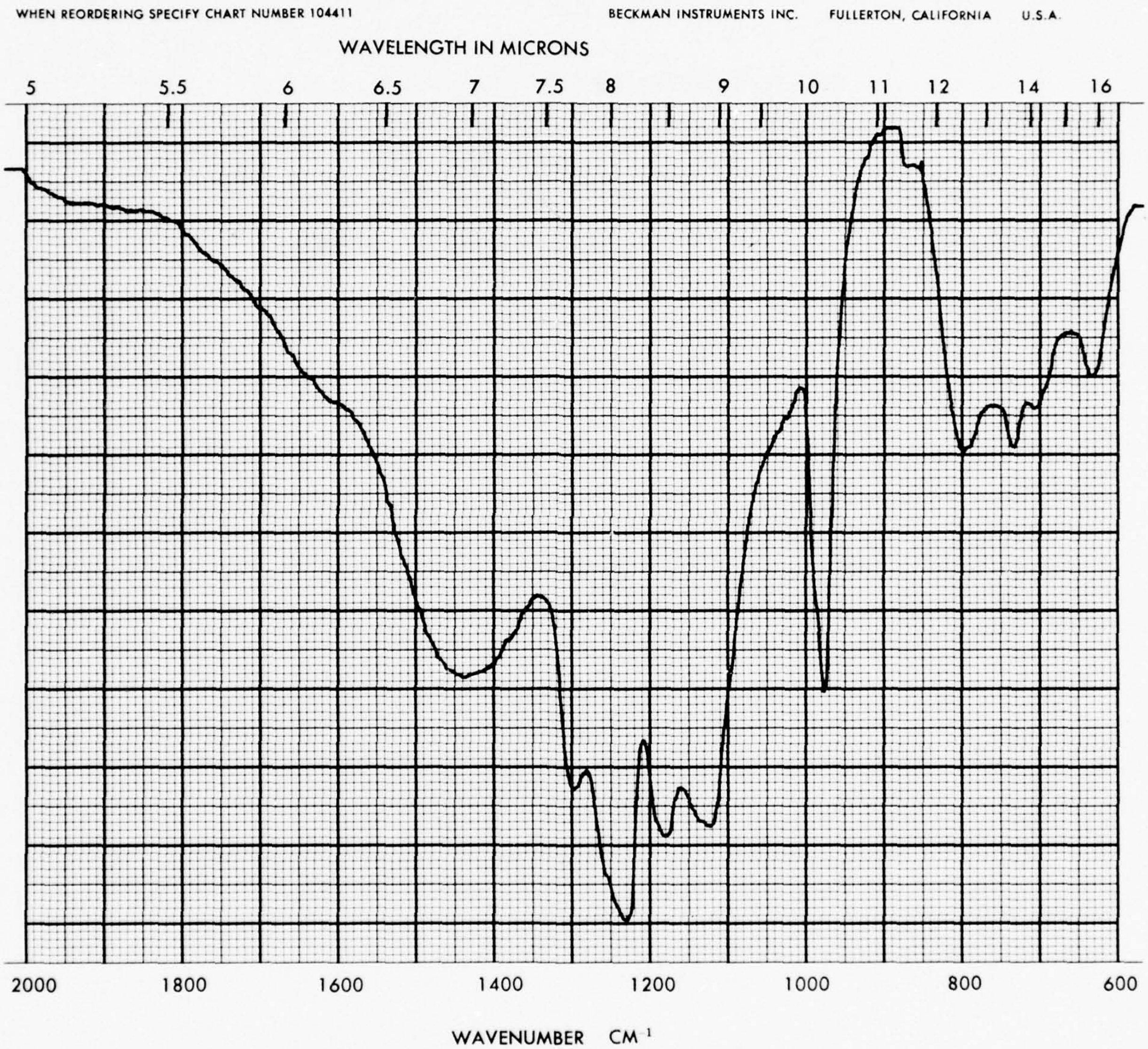

FIGURE 50. MLO-71-6 WHITE DEPOSIT IN OXYGEN DELIVERY TUBE
2000-600 cm^{-1}

TABLE LXXI

MLO-71-6 OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Change, ml. (736 torr, 77 deg. F.) Run 1 (7 hours)
0	0
30	+21.5
60	+13.5
90	+11.7
120	-6.6
150	-2.2
180	0
210	0
240	0
270	0
300	0
330	0
360	0
390	-4.6
420	-0.6
Net Change, ml.	+32.7

TABLE LXXI CONTINUED:

MLO-71-6 OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

	Run 1 (7 hours)
Weight Sample, grams	19.2743
Weight Trap condensate, grams	
Ambient	0.7992
Cold	0.2864
Acid No. of condensate, mg.KOH/gram	
Ambient	1.68
Cold	1.73
Oxidized Oil Properties	
Viscosity @ 100 deg. F., cs.	353.05
% Increase	23.1
Acid No. mg.KOH/gram	0.01

TABLE LXXII

MLO-71-6 with M2 CATALYST OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Changes, ml. Run 1 (756 torr, 77 deg. F.)	Run 2 (748 torr, 83 deg. F.)
0	0	0
15	+11.7	+11.4
30	+15.8	+ 2.8
45	+17.8	+ 5.2
60	+ 4.2	+ 7.1
75	+17.2	+ 8.2
90	+ 7.9	- 1.7
105	+ 8.8	0
120	+14.6	- 1.9
135	+ 9.6	- 2.4
150	+ 8.5	- 3.5
165	+ 7.0	- 5.1
180	0	- 5.3
195	0	- 7.2
210	0	- 4.7
225	- 0.5	- 6.4
240	- 3.5	-10.1
Net Change, ml.	+122.2	-13.6

TABLE LXXII CONTINUED:

MLO-71-6 with M2 CATALYST OXYGEN ABSORPTION TESTS at 650 deg. F. 215 ml/min gas flow rate

	Run 1	Run 2
Weight Sample, grams	19.1167	19.3008
Weight Trap condensate, grams		
Ambient	0.3561	0.4780
Cold	0.1972	0.2441
Acid No. of condensate mg. KOH/gram		
Ambient	2.05	1.88
Cold	36.7	6.34
Oxidized Oil Properties		
Viscosity @ 100 deg. F., cs.	366.97	318.55
% Increase	28.0	11.1
Acid No., mg.KOH/gram	0.01	0.01
M2 Catalyst Wt. change,		
mg/cm^2 (gain)	2.78	
Appearance	Dark Grey	Dark grey
Total acidity of 1 liter reservoir atmosphere, mg.KOH (Absorbed in titration solvent)		13.78

TABLE LXXIII

MLO-71-6 with M10 CATALYST OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Change, ml. (739 torr, 75 deg. F.) Run 1
0	0
15	+20.2
30	+11.5
45	+ 7.1
60	+ 1.8
75	+11.9
90	+13.0
105	+ 2.9
120	- 0.1
135	0
150	- 2.1
165	+ 0.6
180	+ 1.9
195	+ 5.1
210	+ 1.1
225	+ 1.4
240	+ 1.1
Net Change, ml.	+77.4

TABLE LXXIII CONTINUED:

MLO-71-6 with M10 CATALYST OXYGEN ABSORPTION TESTS at 650 deg. F. 215 ml/min gas flow rate

	Run 1
Weight Sample, grams	19.1664
Weight Trap condenstate, grams	
Ambient	0.4215
Cold	0.1631
Acid No. of condensate, mg. KOH/gram	
Ambient	2.42
Cold	2.70
Oxidized Oil Properties	
Viscosity @ 100 deg. F., cs.	339.14
% Increase	18.3
Acid No., mg.KOH/gram	0.01
M10 Catalyst Wt. Change, mg/cm^2 (gain)	0.21
Appearance	Dark Grey

TABLE LXXIV

MLO-71-6 with M50 CATALYST OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

Time, minutes Cumulative	Volume Changes, ml. Run 1 (742 torr, 74 deg. F.)	Run 2 (748 torr, 80 deg. F.)
0	0	0
15	+ 3.9	+ 6.0
30	- 5.0	+ 3.8
45	0	+ 4.8
60	0	+ 7.8
75	- 2.6	+ 2.6
90	- 3.4	0
105	- 5.3	0
120	-13.0	0
135	- 3.2	0
150	-7.3	- 3.6
165	-12.4	0
180	- 8.7	0
195	- 8.0	- 8.8
210	- 8.4	- 5.7
225	- 4.0	- 9.3
240	- 5.7	- 8.9
Net Change, ml.	-83.1	-11.3

TABLE LXXIV CONTINUED:

MLO-71-6 with M50 CATALYST OXYGEN ABSORPTION TESTS
at 650 deg. F. 215 ml/min gas flow rate

	Run 1	Run 2
Weight Sample, grams	19.1794	19.3076
Weight Trap condensate, grams		
Ambient	0.3291	0.6583
Cold	0.1582	0.1490
Acid No. of condensate, mg. KOH/gram		
Ambient	2.86	2.30
Cold	5.45	6.50
Oxidized Oil Properties		
Viscosity @ 100 deg. F., cs.	326.1	348.9
% Increase	13.7	21.7
Acid No., mg.KOH/gram	0.01	0.01
M50 Catalyst Wt. Change, mg/cm^2 (gain)	0.89	0.60
Appearance	Black	Multicolor & 40% Black
Total acidity of 1 liter reservoir atmosphere, mg.KOH (Absorbed in titration solvent)	24.68	

3.3 Conclusions

On the basis of the data which have been obtained it is possible to reach the following conclusions with regard to the method which has been developed for the measurement of the absorption of oxygen at elevated temperatures by lubricants and hydraulic fluids:

3.3.1 Precision

3.3.1.1 Oxygen absorption measurements can be made with a standard deviation of better than 0.1 millimole of oxygen per gram of sample. For absorptions which average 3 or more millimoles of oxygen per gram this represents a percentage deviation of about 3 per cent.

3.3.1.2 The corresponding standard deviations for measurements of oxygen absorption rates (the derivative of total oxygen absorption vs. time) are such as to result in a percentage deviation of between 5 and 10 per cent.

3.3.1.3 The precision of the oxygen absorption measurement techniques which have been developed are more than adequate for use in the evaluation of the reaction of lubricants and hydraulic fluids with oxygen at elevated temperatures.

3.3.2 Oxygen absorption by lubricants and hydraulic fluids.

3.3.2.1 The extent of oxygen absorption by a sample was found to be highly dependent upon the rate at which oxygen was passed through it at all rates which could be conveniently run in the present apparatus. Although it is probable that a limiting rate could be achieved, above which absorption would not be increased by further increases in flow rate, no such effect was observed within the range of flow rates which was studied. Except for the initial rate studies, all additional measurements made during the course of this study were made at an oxygen flow rate of 215 ml/min in the standard apparatus. The rate was sufficiently high to produce a readily measurable absorption which was still not too fast to permit convenient measurement by the manual technique.

3.3.2.2 Induction periods for oxygen absorption appear to be dependent on flow rate as well. There may be a limiting, non-zero induction period which is reached at sufficiently high flow rate so that further elevation of the flow rate causes no further decrease in induction period. For the present sample, MLO-69-35, this period appears to be about 14.5 minutes. However, additional studies with this and other samples appear to be necessary before further generalizations can be made on this point.

3.3.2.3 In the case of MLO-69-35 oxygen absorption rates pass through a maximum just after the induction period and then approach a final limiting rate which appears to be maintained for an indefinite (but necessarily finite) time. This limiting rate is also a function of oxygen flow rate through the sample. At higher flow rates a constant value is approached, so that above 215 ml/min oxygen flow rate through MLO-69-35 a limiting absorption rate of about 11 micromoles of oxygen/gram/min. is attained.

3.3.2.4 In the case of sample number MLO-69-35 the changes in the acid number and viscosity of the sample are consistent with the degree of oxygen absorption obtained under any given set of test parameters.

3.3.2.5 The effectiveness of additives and additive packages can be clearly illustrated by oxygen absorption data. It is particularly interesting to note the effectiveness of additives in increasing the induction period during which little or no oxygen absorption occurs. See Figures 37 and 38 which illustrate this effect for MLO-69-35 and blends of that sample with 5-10-10 and pana additives. While total oxygen absorption is also effectively reduced by the additives, the limiting final rate of reaction appears to be higher in the presence of additives than in the base stock at least for the MLO-69-35 systems studied. Further studies should be performed to elucidate this phenomenon in greater detail.

3.3.2.6 In the case of MLO-71-6 there was no clear cut evidence that oxygen absorption occurred even at 650 deg. F. The most likely course of reaction probably involves evolution of gaseous oxidation or decomposition products in conjunction with some oxygen absorption. In any case the net volume changes are very small: within ± 0.05 millimoles/gram for the neat sample and within about ± 0.2 millimoles/gram in the presence of various steel catalysts. For these reasons no attempt was made to calculate net oxygen absorption or absorption rates for this sample. There is strong evidence to indicate that the decomposition or oxidation of MLO-71-6 involves the production of gaseous hydrogen fluoride. The walls of the glass apparatus were severely etched and acidic gases were collected in the gas reservoir. Infrared analysis of some of the oxidation and degradation products of the sample suggests that a number of non-fluorocarbon reaction products have been formed.

SECTION IV

MISCELLANEOUS CHEMICAL AND PHYSICAL PROPERTIES

4.1 Experimental Results:

Tables LXXV through CXXXIV and Figures 51 through 92 summarize the data which have been obtained:

TABLE LXXV

SAMPLE NUMBER MIL-H-5606

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 275 deg. F.	73.4

TABLE LXXVI

SAMPLE NUMBER MLO H 5606B

HYDROLYTIC STABILITY TEST
ASTM D 2619
(48 hours @ 200 deg. F.)

Corrosion:

1. Change in weight of copper, mg./sq.cm:	-0.11
2. Appearance of copper	Moderate tarnish 2B

Resistance to Hydrolysis:

1. Viscosity @ 100 deg. F., cs.	
a. Original sample	14.94
b. After test	15.21
c. Change, %	+1.8
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	2.51
b. Organic layer	0.09
After test	0.04
Change	-0.05
3. Insoluble material in oil layer, %	0.001

TABLE LXXVII

SAMPLE NUMBER MCG-68-63

COEFFICIENT OF FRICTION
FOUR-BALL METHOD

CONDITIONS

Load, Kg	20
RPM	1200
Temp. °F.	167
Time, min.	1

Type of Balls	Coefficient of Friction
52100	
Run 1	0.0950
Run 2	0.0975
M-10	
Run 1	0.0789
Run 2	0.0780
M-50	
Run 1	0.0856
Run 2	0.0805
440C	
Run 1	0.0806
Run 2	0.0797

TABLE LXXVIII

SAMPLE NUMBER MCG 7319925

COEFFICIENT OF FRICTION

FOUR-BALL METHOD

CONDITIONS

Load, Kg	20
RPM	1200
Temp. °F.	167
Time, min.	1

Type of Balls	Coefficient of Friction
52100	
Run 1	0.1077
Run 2	0.1013
M-10	
Run 1	0.0873
Run 2	0.0878
M-50	
Run 1	0.0814
Run 2	0.0827
440C	
Run 1	0.0890
Run 2	0.0907

TABLE LXXIX

SAMPLE NUMBER MCG 68-63
SAMPLE NUMBER MCG 72-11
SAMPLE NUMBER MCG 7319925
SAMPLE NUMBER MCG 7327833

DIRT COUNT
FTM Std. 791b
Method 3005.3
Modified

Sample Number	Particles/cm^3	
	10 - 35 mm.	Greater than 35
MCG 68-63	836	139
MCG 72-11	13,208	199
MCG 7319925	666	148
MCG 7327833	892	111

TABLE LXXX

SAMPLE NUMBER MLO-68-1

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 275 deg. F.	0.2

TABLE LXXXI

SAMPLE NUMBER MLO-69-35

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 400 deg. F.	3.0

TABLE LXXXII

99% MLO-71-6
1% HG-74-32

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
24 hrs. @ 600 deg. F.

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.02		288.6	28.10		
16 hours	0.03	+0.01	289.8	28.09	0.4	0.0
24 hours	0.04	+0.02	291.6	28.24	1.0	0.5

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	Slight pitting around hole & multicolor discoloration
Aluminum	0.00	Light brown & faint purple discoloration
Bronze	0.00	Dark brown discoloration
Silver	-0.04	Moderate tarnish
Steel M-50	0.00	Dark purple discoloration
Mild Steel	0.00	Olive green & multicolor discoloration
Titanium	0.00	Brown discoloration

Evaporation Loss, %	0.8
Appearance of tube	Clean
Appearance of oil	Light brown, no precipitate
Sludge by centrifuge	None

TABLE LXXXIII

SAMPLE NUMBER MLO-71-18

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 400 deg. F.	2.8

TABLE LXXXIV

SAMPLE NUMBER MLO-71-37

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 275 deg. F.	27.4

TABLE LXXXV

SAMPLE NUMBER MLO-71-45

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 275 deg. F.	1.8
6½ hours @ 400 deg. F.	20.9

TABLE LXXXVI

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
No Catalyst
Duration of Test, hrs. 6½

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.90
Change, %	+1.1
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.05
Change	+0.04
Appearance after exposure	Clear, the color is darker than that of the original sample.
Pressure rise at end of test, psi	7

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
No Catalyst
Duration of Test, hrs. 24

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.72
Change, %	0.00
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.27
Change	+0.26
Appearance after exposure	No precipitate; color is darker than that of the original sample.
Pressure rise at end of test, psi	7

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
No Catalyst
Duration of Test, hrs. 48

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.73
Change, %	+0.06
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.26
Change	+0.25
Appearance after exposure	No precipitate; color is darker than that of the original sample.
Pressure rise at end of test, psi	None

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 MODIFIED

Temperature, deg. F. 400
No Catalyst
Duration of Test, hrs. 48

SECOND RUN

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.82
Change, %	+0.6
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.58
Change	+0.57
Appearance after exposure	Clear, no precipitate
Pressure rise at end of test, psi	7

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
No Catalyst
Duration of Test, hrs. 72

Viscosity @ 100 deg. F., cs:	
Before exposure	15.73
After exposure	15.93
Change, %	+1.3
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.76
Change	+0.75
Appearance after exposure	Clear, the color is darker than that of the original sample.
Pressure rise at end of test, psi	7

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
#304 Stainless Steel Catalyst
Duration of Test, hrs. 6½

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.78
Change, %	+0.4
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.02
Change	+0.01
Appearance after exposure	Clear, no precipitate
Change in weight of metal specimen, mg./sq.cm.	0.00 *
Pressure rise at end of test, psi	6

* Very faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
#304 Stainless Steel Catalyst
Duration of Test, hrs. 24

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.65
Change, %	-0.4
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.17
Change	+0.16
Appearance after exposure	Clear, no precipitate
Change in weight of metal specimen, mg./sq.cm.	0.00 *
Pressure rise at end of test, psi	6

* Very faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 MODIFIED

Temperature, deg. F. 400
#304 Stainless Steel Catalyst
Duration of Test, hrs. 48

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.72
Change, %	0.00
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.39
Change	+0.38
Appearance after exposure	Clear, no precipitate
Change in weight of metal specimen, mg./sq.cm:	0.00 *
Pressure rise at end of test, psi	6

* Very faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
#304 Stainless Steel Catalyst
Duration of Test, hrs. 72

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.77
Change, %	+0.3
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.49
Change	+0.48
Appearance after exposure	Clear, the color is darker than that of the original sample.
Change in weight of metal specimen, mg./sq.cm.	0.00 *
Pressure rise at end of test, psi	6

* Very faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
Cast Iron Catalyst
Duration of Test, hrs. 6½

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.67
Change, %	-0.3
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.01
Change	0.00
Appeearance after exposure	No precipitate; color is darker than that of the original sample.
Change in weight of metal specimen, mg./sq.cm:	+0.27 *
Pressure rise at end of test, psi	7

* No discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
Cast Iron Catalyst
Duration of Test, hrs. 24

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.72
Change, %	0.00
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.14
Change	+0.13
Appearance after exposure	No precipitate; color is darker than that of the original sample.
Change in weight of metal specimen, mg./sq.cm.	+0.38 *
Pressure rise at end of test, psi	7

* Faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
Cast Iron Catalyst
Duration of Test, hrs. 48

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.70
Change, %	-0.1
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.70
Change	+0.69
Appearance after exposure	No precipitate; color is darker than that of the original sample.
Change in weight of metal specimen, mg./sq.cm.	+0.17 *
Pressure rise at end of test, psi	7

* Faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 Modified
Temperature, deg. F. 400
Cast Iron Catalyst
Duration of Test, hrs. 72

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.67
Change, %	-0.3
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.50
Change	+0.49
Appearance after exposure	Clear, the color is darker than that of the original sample.
Change in weight of metal specimen, mg./sq.cm.	+0.11 *
Pressure rise at end of test, psi	7

* Faint brown discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

THERMAL STABILITY TEST
MIL-H-27601 MODIFIED
Temperature, deg. F. 400
Cast Iron Catalyst
Duration of Test, hrs. 72

RUN 2

Viscosity @ 100 deg. F., cs:	
Before exposure	15.72
After exposure	15.58
Change, %	-0.9
Neutralization No., mg.KOH/g:	
Before exposure	0.01
After exposure	0.70
Change	+0.69
Appearance after exposure	Light yellow, slightly turbid and light brown precipitate
Change in weight of metal specimen, mg./sq.cm:	-0.74*
Pressure rise at end of test, psi	7

* Corrosion, light brown deposit, multicolor and dark gray discoloration

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

COMMENT

In one of the replicate thermal stability tests conducted on the subject sample for 72 hours at 400 deg. F. with a cast iron catalyst a light brown precipitate formed. No similar precipitate was found in any of the other thermal stability determinations. To identify the nature of the precipitate the sample and the precipitate were subjected to infrared analysis as follows:

INFRARED ANALYSIS

The sample and its residues were subjected to infrared analysis as indicated in the following table:

LABORATORY NUMBER	SAMPLE OR FRACTION	APPEARANCE	METHOD OF PREPARATION
MLO-72-108	New oil as received	Greenish-yellow oil	1
MLO-72-108	Insoluble precipitate formed during thermal stability test	Light brown to gray powdery solid	2, 3a, 4
MLO-72-108	Residue formed on cast iron catalyst during thermal stability test	Gray adhering powder	2, 5

KEY TO METHODS OF PREPARATION

(1) Thin film between potassium bromide plates.

(2) Potassium bromide pellet.

(3) Drying procedure used to remove residual solvents:

  (a) Dried at 90 deg. C.

(4) Precipitate washed with hexane.

(5) Adhering residue removed from cast iron test piece by potassium bromide abrasion.

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CHEMICAL AND PHYSICAL PROPERTIES OF LUBRICANTS AND HYDRAULIC FL--ETC(U)
JUN 76 A A KRAWETZ, G A KRAWETZ, T TOVROG F33615-73-C-5103

UNCLASSIFIED AFML-TR-76-166 NL

3 OF 4
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A037299

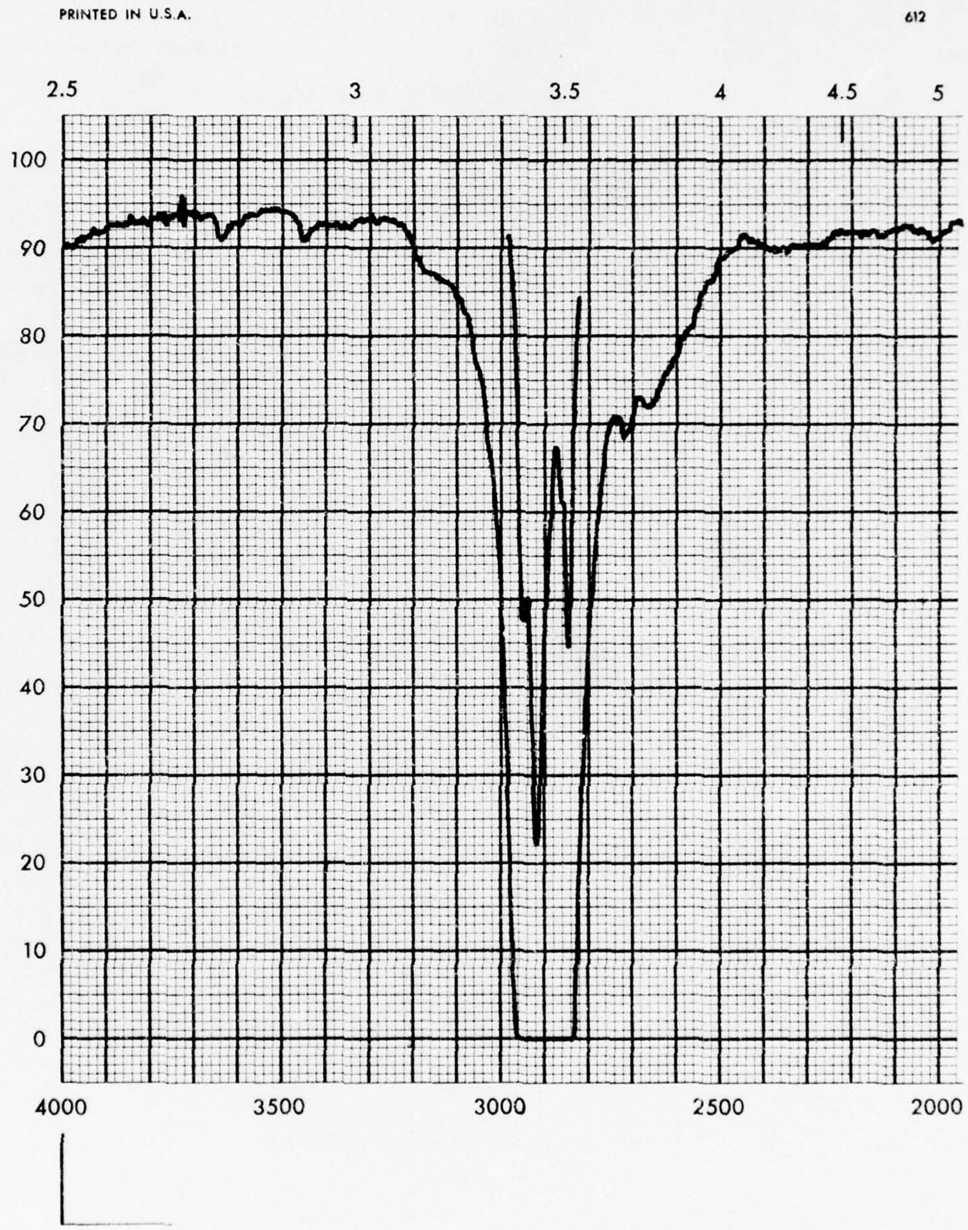

FIGURE 51. MLO-72-108. INFRARED SPECTRUM OF NEW OIL AS RECEIVED. 4000 to 2000 cm^{-1}

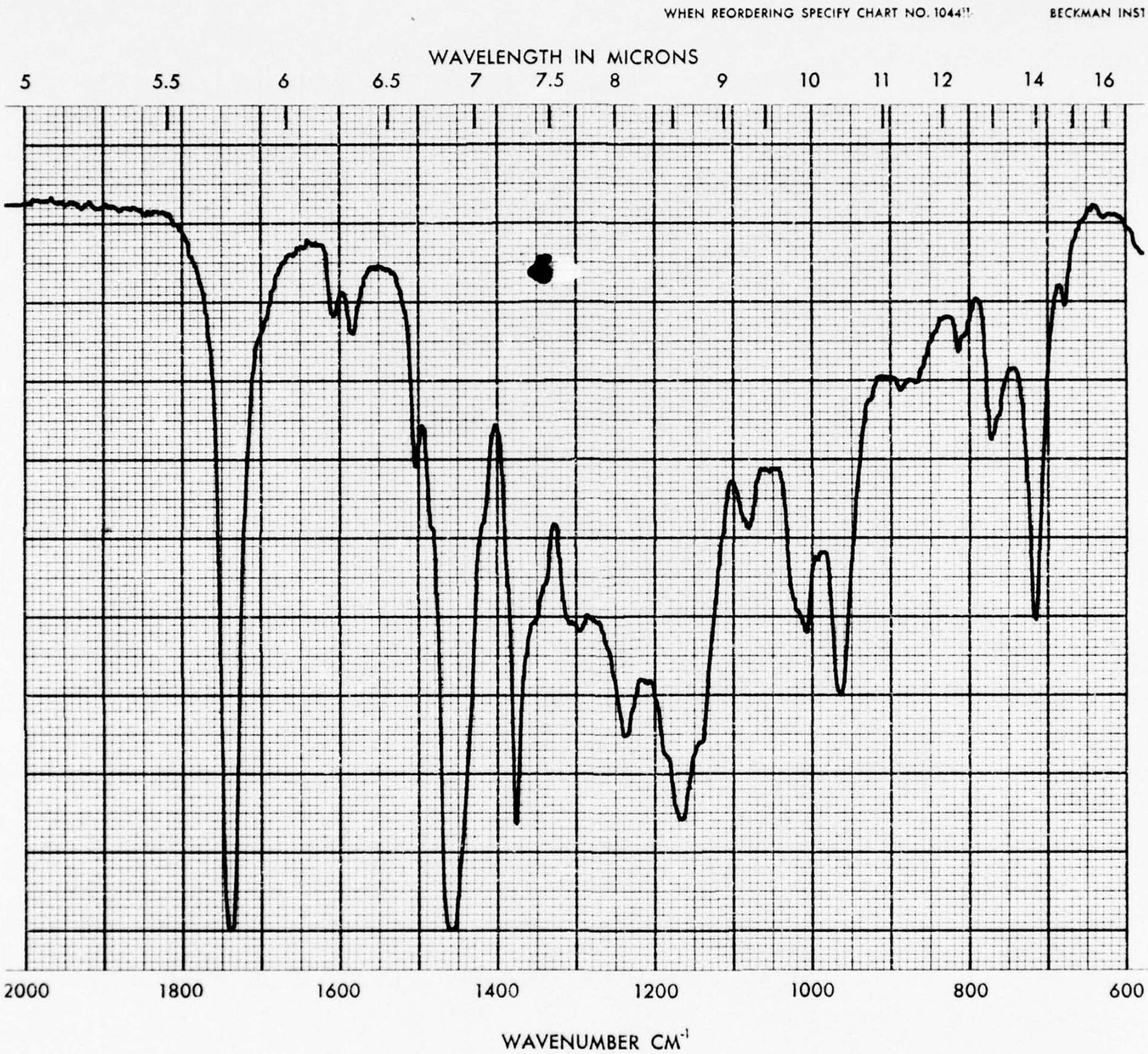

FIGURE 52. MLO-72-108. INFRARED SPECTRUM OF NEW OIL AS RECEIVED.
2000 to 600 cm^{-1}

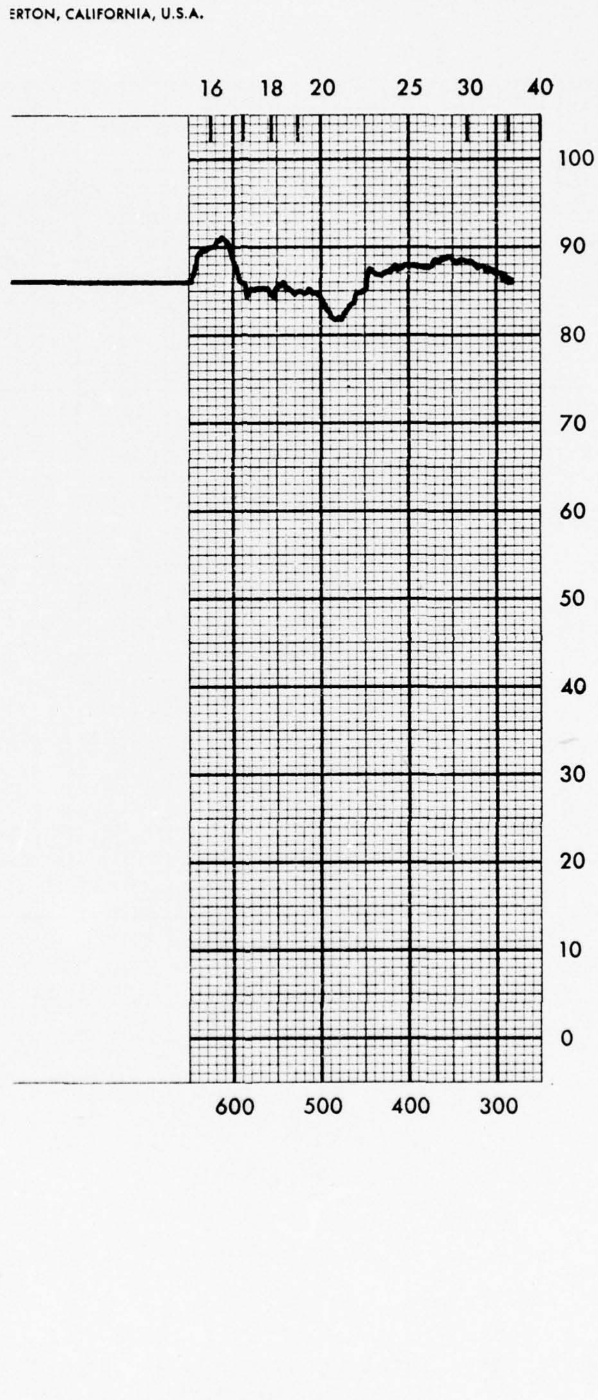

FIGURE 53. MLO-72-108. INFRARED SPECTRUM OF NEW OIL AS RECEIVED. 600 to 300 cm^{-1}

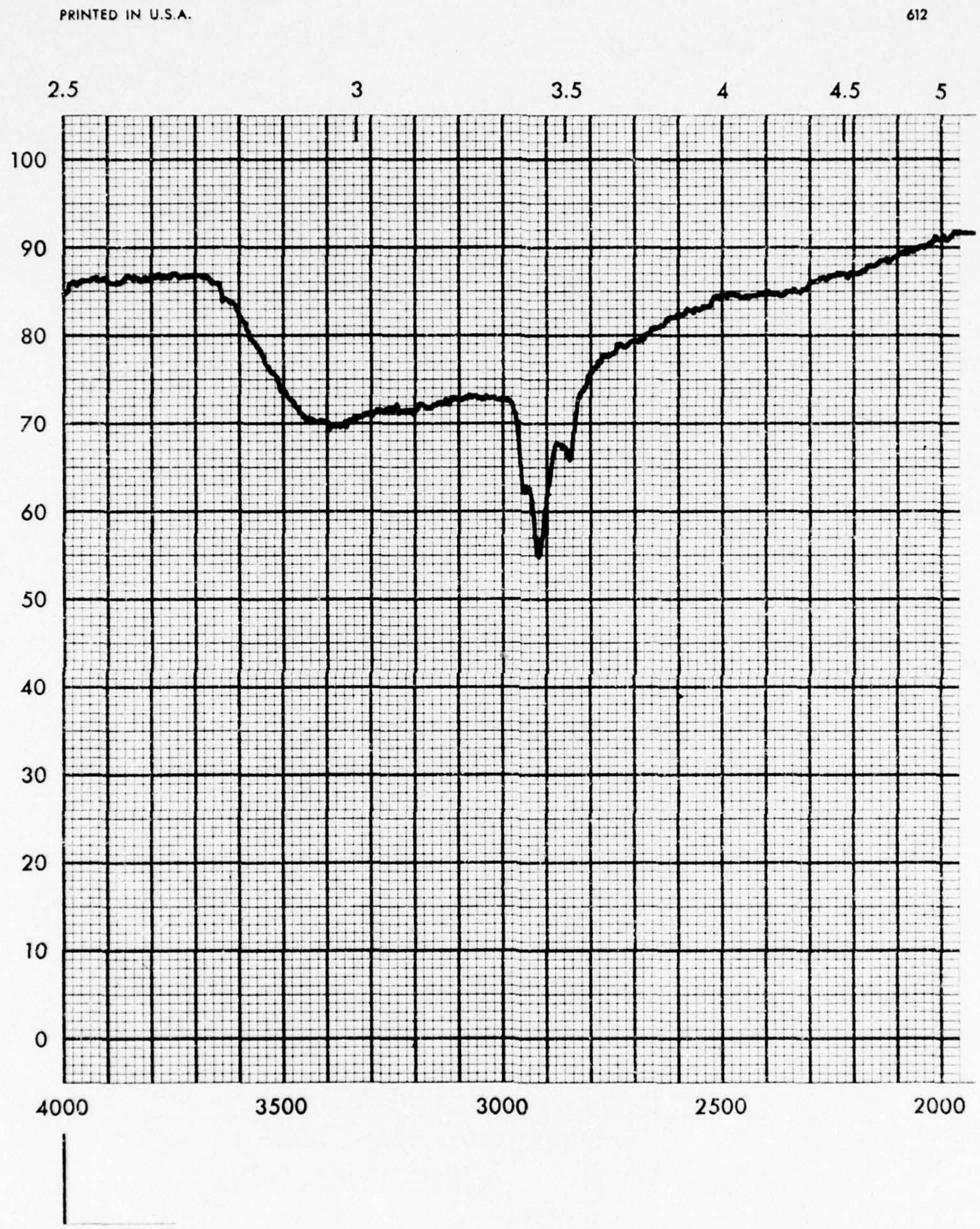

FIGURE 54. MLO-72-108. INFRARED SPECTRUM OF INSOLUBLE PRECIPITATE FORMED DURING THERMAL STABILITY TEST. 4000 to 2000 cm^{-1}

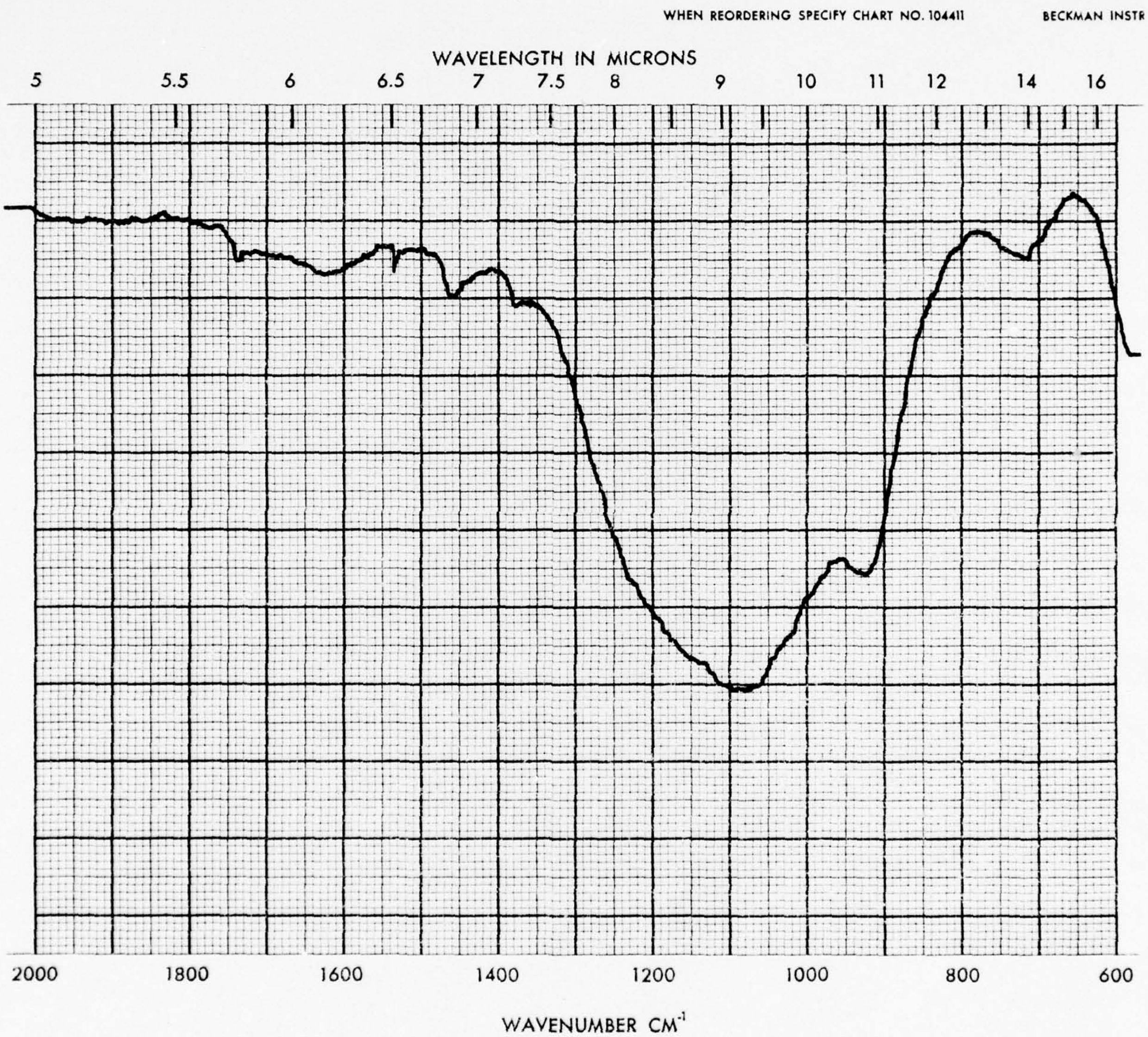

FIGURE 55. MLO-72-108. INFRARED SPECTRUM OF INSOLUBLE PRECIPITATE FORMED DURING THERMAL STABILITY TEST. 2000 to 600 cm^{-1}

:RTON, CALIFORNIA, U.S.A.

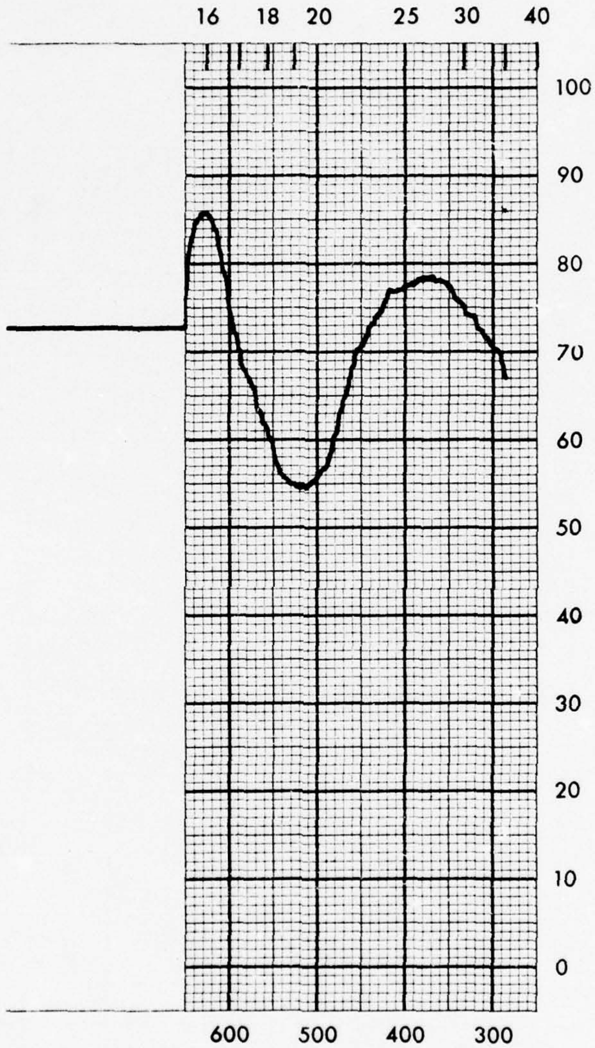

FIGURE 56. MLO-72-108. INFRARED SPECTRUM OF INSOLUBLE PRECIPITATE FORMED DURING THERMAL STABILITY TEST.
600 to 300 cm^{-1}

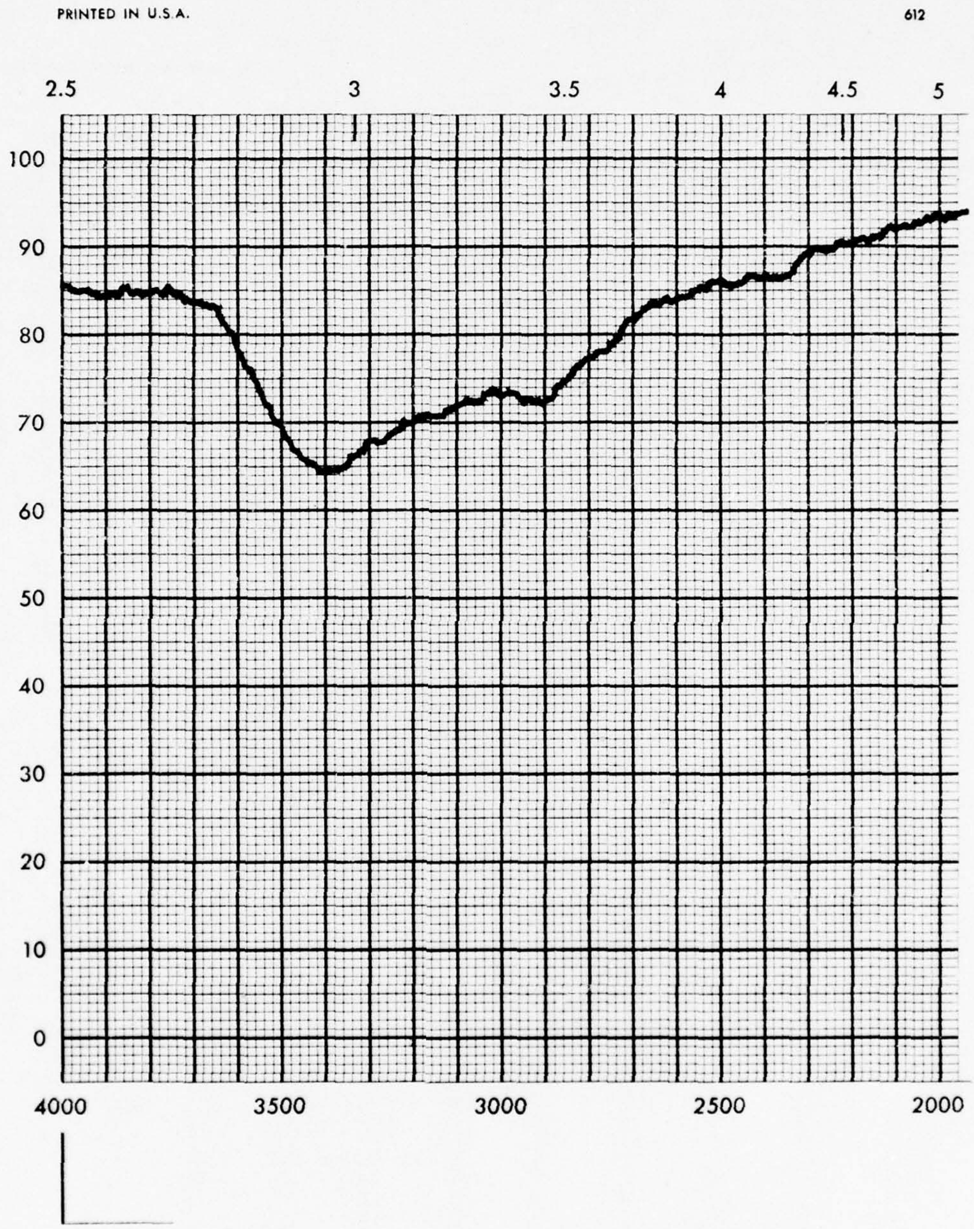

FIGURE 57. MLO-72-108. RESIDUE FORMED ON IRON CATALYST DURING THERMAL STABILITY TEST. 4000 to 2000 cm^{-1}

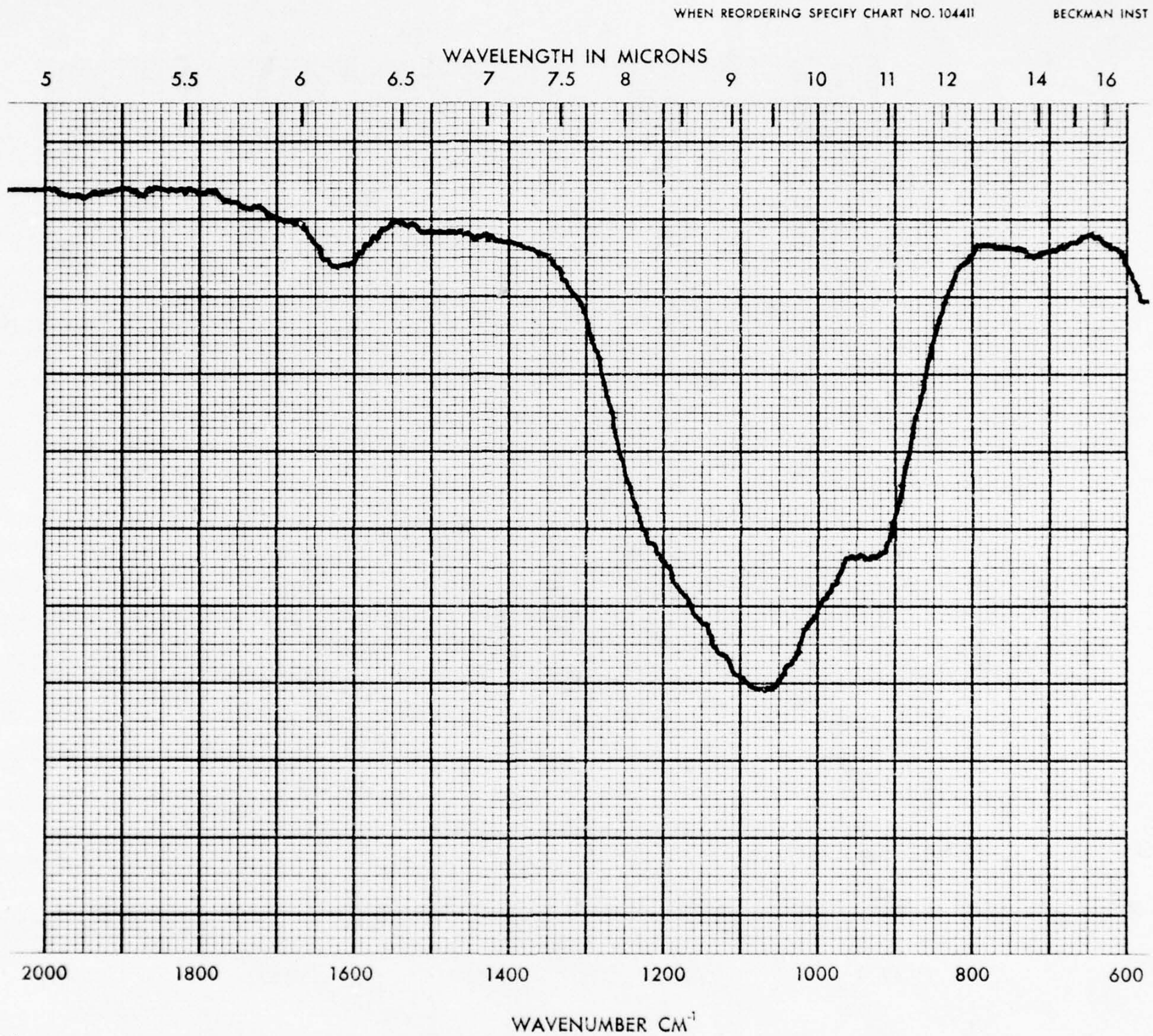

FIGURE 58. MLO-72-108. RESIDUE FORMED ON IRON CATALYST DURING THERMAL STABILITY TEST. 2000 to 600 cm^{-1}

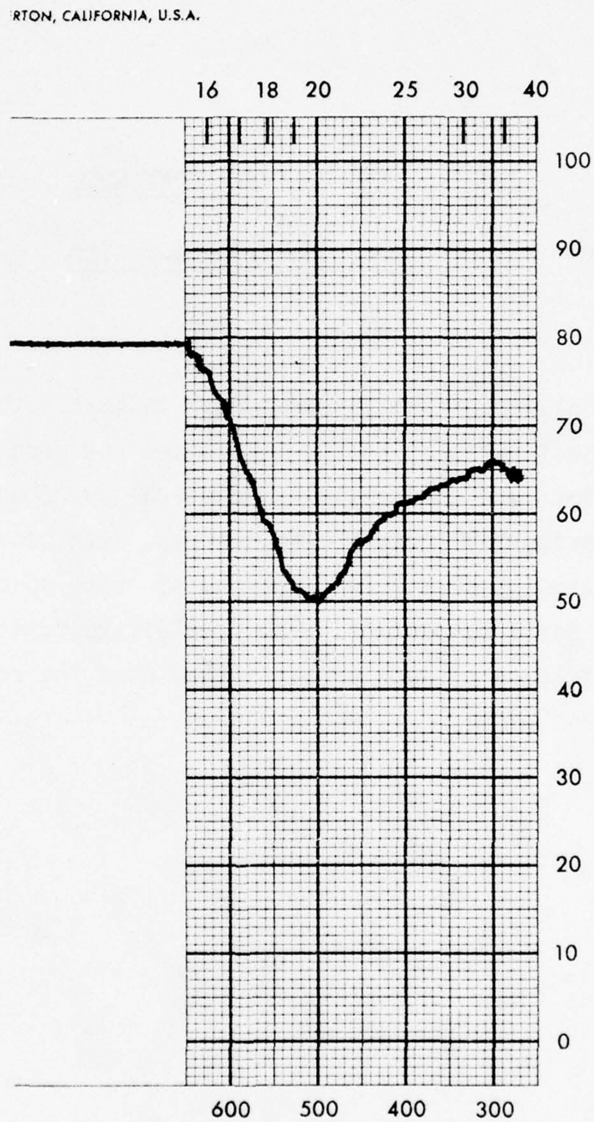

FIGURE 59. MLO-72-108. RESIDUE FORMED ON IRON CATALYST DURING THERMAL STABILITY TEST. 600 to 300 cm^{-1}

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

Analysis of the infrared data indicates that the insoluble precipitate present in the sample and the deposit on the cast iron test piece are substantially identical in composition. Both appear to be primarily inorganic in nature. Both consist essentially of phosphates, probably iron phosphate. Each specimen also contains some organic components. The precipitate contains a higher concentration of such organics than does the residue from the cast iron test piece.

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

SPECIFIC GRAVITY

Specific Gravity @ 100/60 deg. F.	0.8323
Specific Gravity @ 250/60 deg. F.	0.7787

THERMAL CONDUCTIVITY TEST

BTU/hr $(Ft)^2(^oF/Ft)$

Temperature, deg. F.	
100	0.086
250	0.081

TABLE LXXXVI CONTINUED

SAMPLE NUMBER MLO-72-108

SPECIFIC HEAT

Temperature, Deg. F.	Specific Heat
100	0.517
150	0.543
200	0.569
250	0.595

TABLE LXXXVII

SAMPLE NUMBER MLO-73-6
AND BLENDS WITH MIL-H-5606B

AUTOIGNITION TEMPERATURE
ASTM D 2155

MLO-73-6	MIL-H-5606B	Minimum Ignition Temperature, deg. F.	Ignition Delay, Seconds
100	0	700	2.1
97	3	705	2.4
95	5	700	5.7
90	10	705	3.8
75	25	655	1.2
0	100	465	59.7

TABLE LXXXVIII

SAMPLE NUMBER MLO-73-45

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 400 deg. F.	11.6

TABLE LXXXIX

SAMPLE NUMBER MLO-73-51

THERMAL STABILITY TEST
MIL-H-27601
(6 hours @ 350 degrees F.)

Viscosity @ 100 deg. F., cs:	
Original	7.85
After exposure	7.78
% change	-0.9
Neutralization No., mg.KOH/g:	
Original	0.02
After exposure	0.02
Change	0.00
Appearance after exposure:	Clear, no precipitate
Change in Weight of Metals, mg./sq.cm:	
M-10	0.00
Brass	0.00*
52-100	0.00

* Olive green discoloration

TABLE LXXXIX CONTINUED

SAMPLE NUMBER MLO-73-51

Viscosity @ -65 deg. F., cs.	3053
Elastomer Compatibility (MIL-H-83282) % Swell	20.44

THERMAL STABILITY TEST
MIL-H-27601
(6 hours @ 400 degrees F.)

Viscosity @ 100 deg. F., cs:	
Original	7.85
After exposure	7.59
% decrease	-3.3
Neutralization No., mg.KOH/g:	
Original	0.02
After exposure	0.02
Change	0.00
Appearance after exposure:	Clear, no precipitate
Change in Weight of Metals, mg./sq.cm:	
M-10	0.00
Brass	0.00 *
52-100	0.00

* Light bronze discoloration

TABLE LXXXIX CONTINUED

SAMPLE NUMBER MLO-73-51

Evaporation Loss, % (6½ hours @ 300 deg. F.)	9.6

TABLE LXXXIX CONTINUED

SAMPLE NUMBER MLO-73-51

REACTION THRESHOLD TEMPERATURE
(PHOENIX CHEMICAL LABORATORY, INC. METHOD)

Run No.	Sample Size, ml.	Initial Temp., deg. F.	Max. Rise, deg. F.	Pre-Ignition Flame	Cool Flame	Hot Flame	Delay, Sec.	Observations
1	1.0	423	6	X			-	
2		430	5	X			-	
3		432	362			X!	45, 246	Flame, explosion
4		435	292			X!	50, 139	Flame, explosion
5		451	469			X	67	Flame, explosion
6		474	537			XM	7	Flame, explosion
7		495	504			XM	19	Flame, explosion
8	0.5	416	9	X			-	
9		424	9	X			-	
10		429	222			X	43	Flame, explosion
11		435	8	X			-	Smoke
12		436	361			X!	53, 221	Flame, explosion
13		440	314			X!	44, 188	Smoke, flame, explosion
14		450	294			X!	34, 140	Smoke, flame, explosion
15	0.2	405	1	X			-	
16		411	2	X			-	
17		413	4	X			-	
18		415	5	X			-	
19		420	9	X			-	
20		426	6	X			-	

TABLE LXXXIX CONTINUED

SAMPLE NUMBER MLO-73-51

REACTION THRESHOLD TEMPERATURE
(PHOENIX CHEMICAL LABORATORY, INC. METHOD)

Run No.	Sample Size, ml.	Initial Temp., deg. F.	Max. Rise, deg. F.	Pre-Ignition Flame	Cool Flame	Hot Flame	Delay, Sec.	Observations
21	0.2	430	9	X			-	
22		430	9	X			-	Smoke
23		435	9	X			-	Smoke
24		439	227			X	204	Flame, explosion
25		441	320			X	170	Flame, explosion
26		442	375			X!	38, 182	Gold flame, explosion
27		443	295			X!	33, 150	Gold flame, explosion
28		491	375			XM	8	Flame, explosion
29		535	296			X	4	Gold flame
30		563	278			X	2	Gold flame
31		605	230			X	2	Gold flame
32		640	135			X	2	Gold flame
33		696	273			X	1	Gold flame
34	0.1	430	7	X			-	
35		435	11	X			-	Smoke
36		440	236			X!	36, 151	Flame, explosion
37		449	241			X!	37, 142	Smoke, flan explosion

X! Indicates reaction which exhibits both cool-flame and hot-flame characteristics.

XM Indicates multiple hot and cool-flame ignitions.

MLO-73-51. See Table LXXXIX and Figures 60 through 72.

Cool-flame ignitions, per se, were not observed during the study of the processes surrounding the spontaneous ignition of the sample. In several instances cool flames were found to precede rather energetic hot-flame ignitions. See Runs 3, 12 and 27, Figures 60 through 62. The majority of the hot-flame ignitions which were detected were of the standard type. They did, however, appear to be somewhat more energetic than average. Runs 5 and 29, Figure 63 and 64, are examples of these reactions. Some multiple hot-flame ignitions were observed. See, for example, Runs 6 and 7, Figures 65 and 66. At lower temperatures typical pre-flame reactions were found for each sample series. See Runs 2, 9, 20, 22 and 34, Figures 67 through 71.

The minimum spontaneous ignition temperature of the sample as determined from Figure 72 is 429 deg. F. The pre-flame reaction threshold temperature for the 0.2 ml. sample series is 405 deg. F.

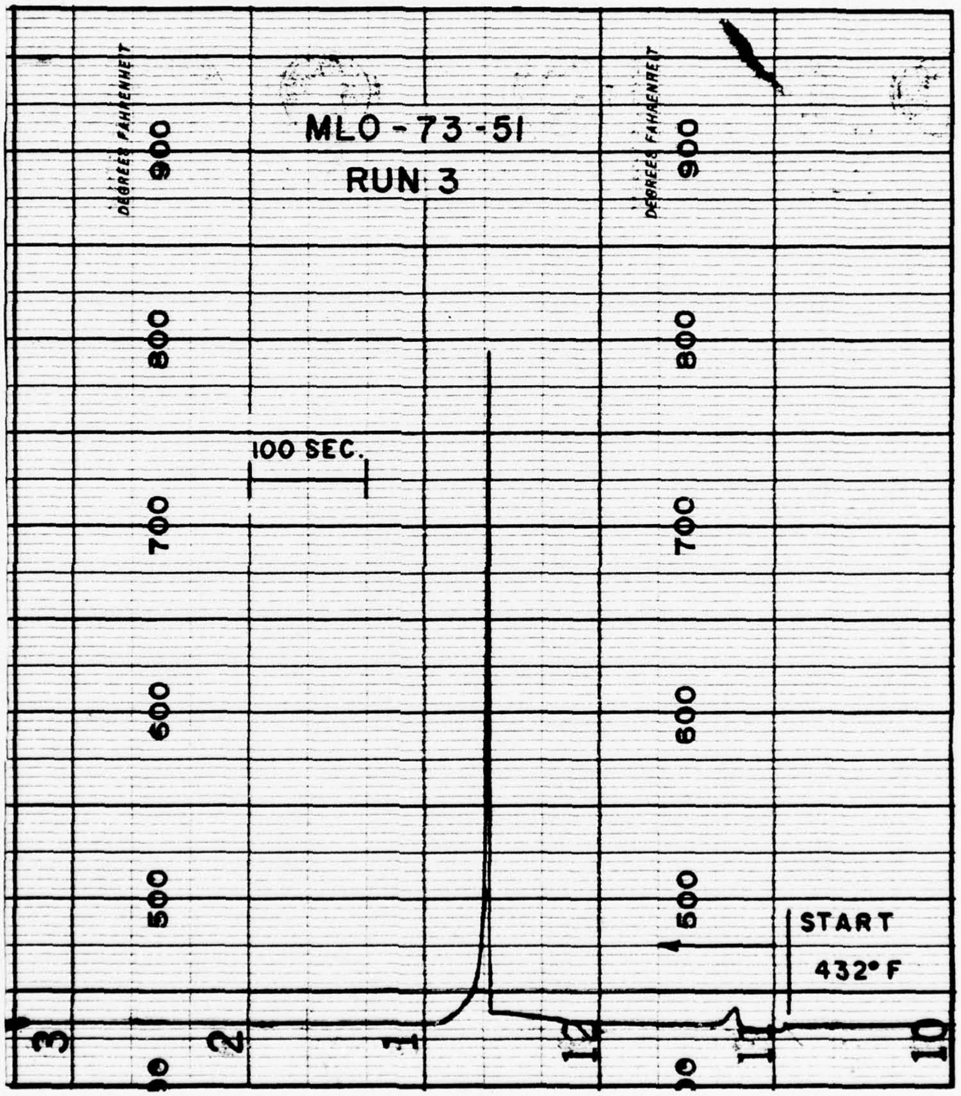

FIGURE 60. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 3.

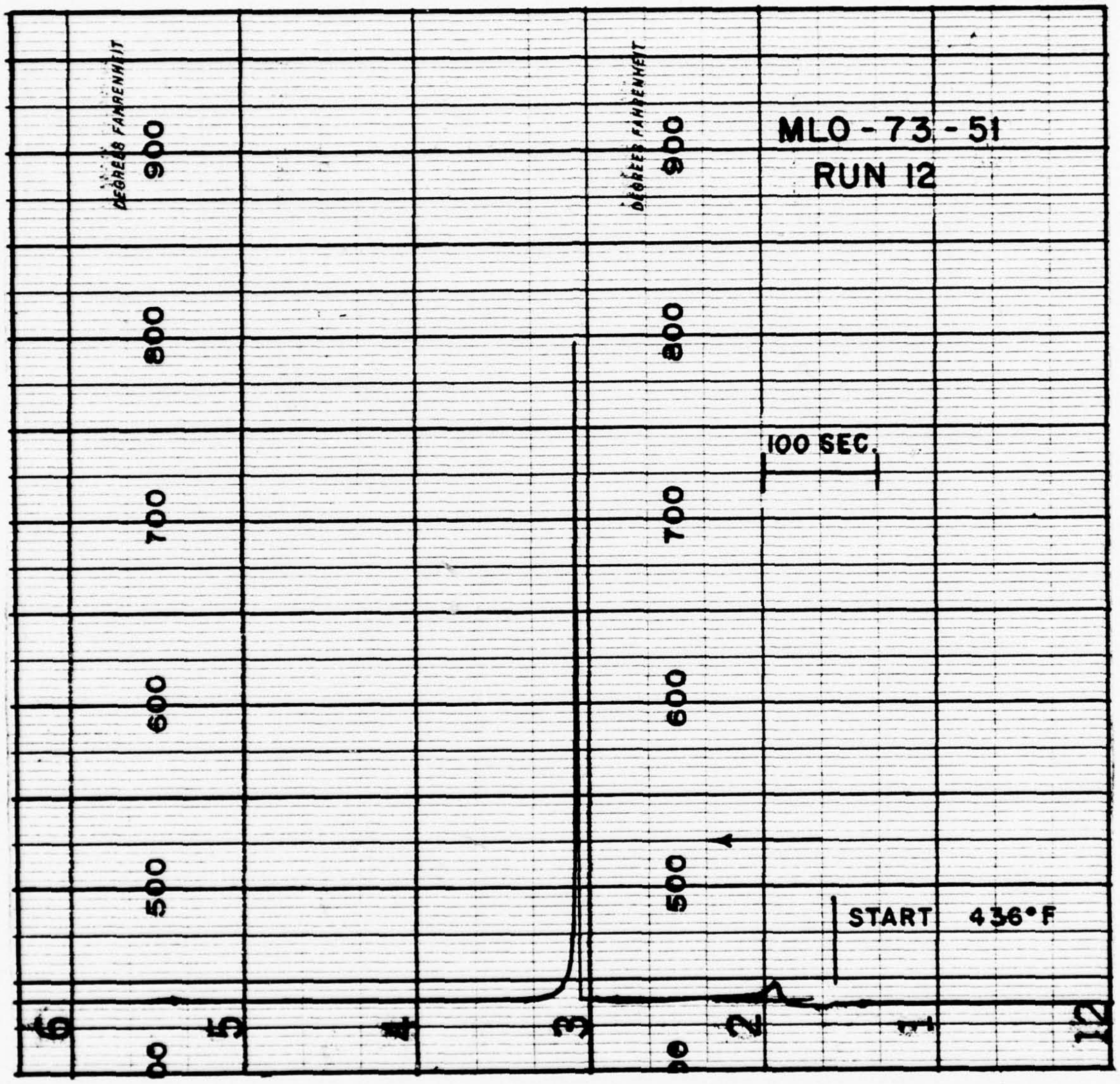

FIGURE 61. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 12.

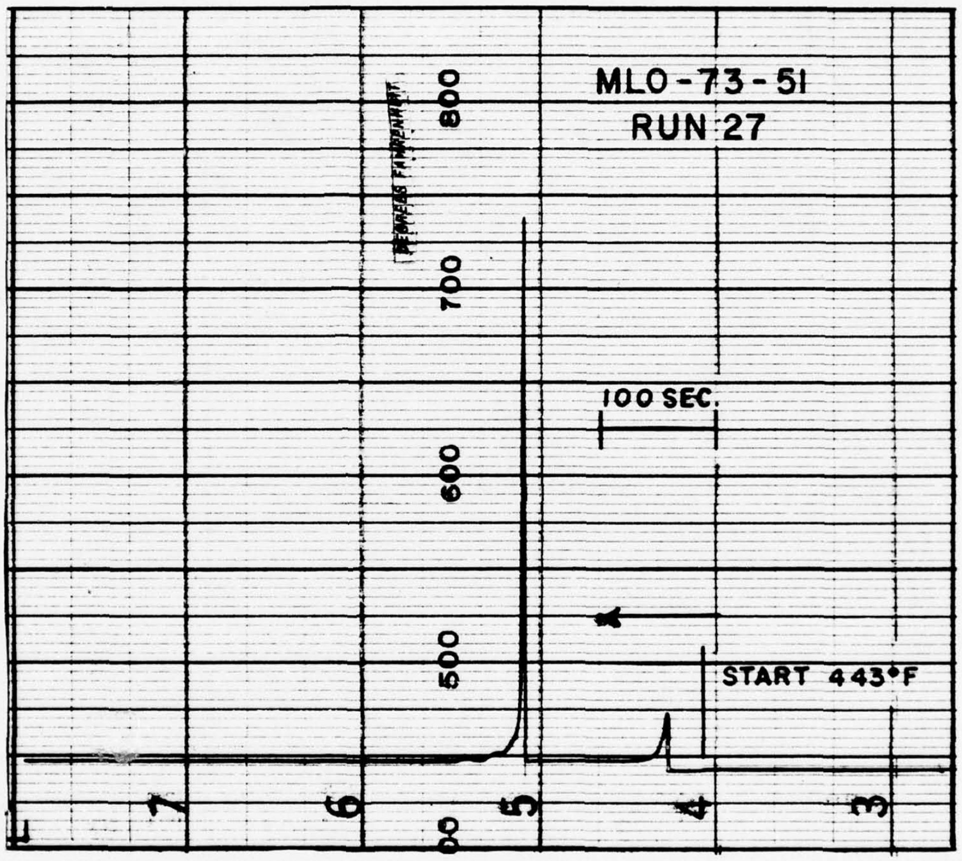

FIGURE 62. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 27.

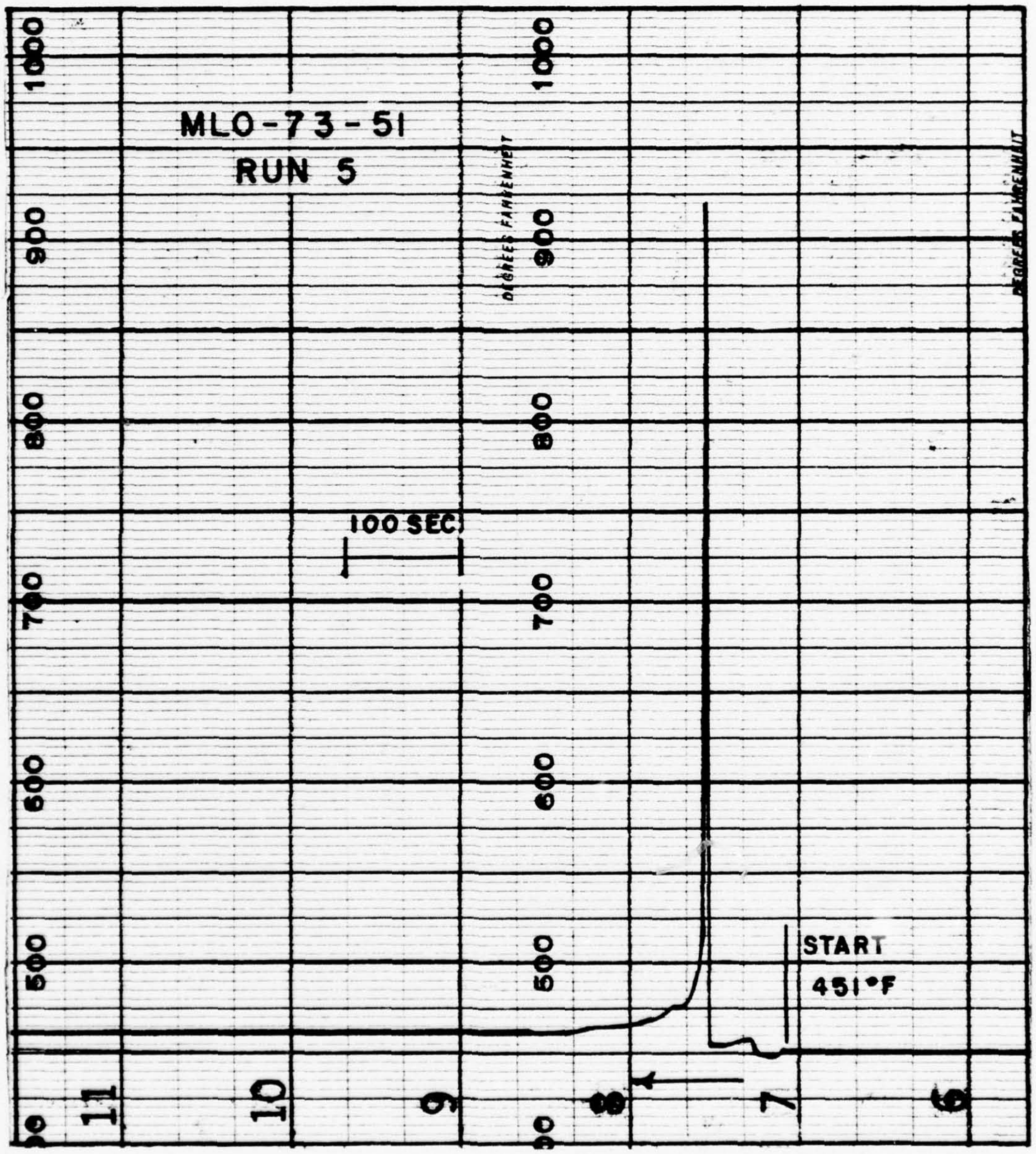

FIGURE 63. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 5.

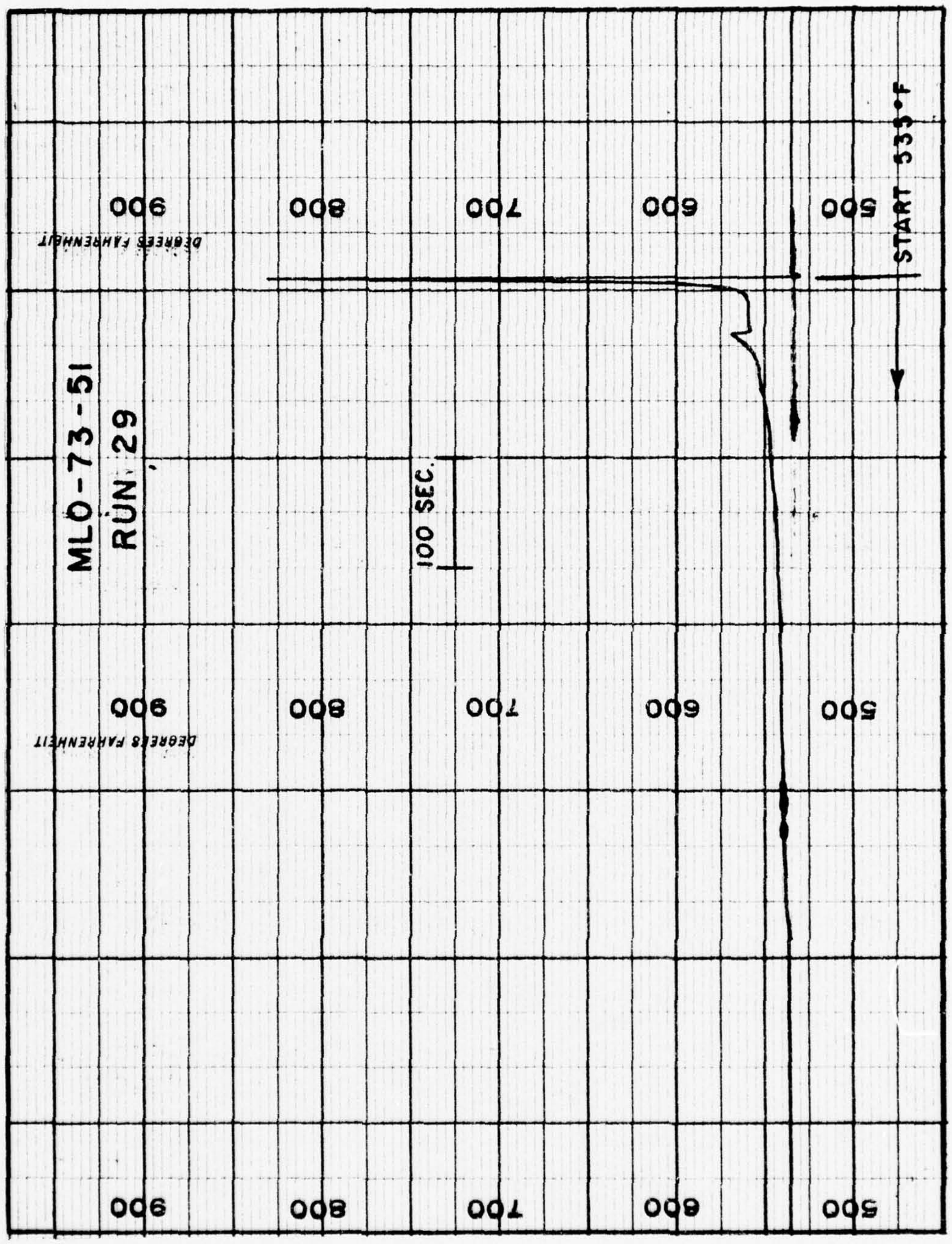

FIGURE 64. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 29.

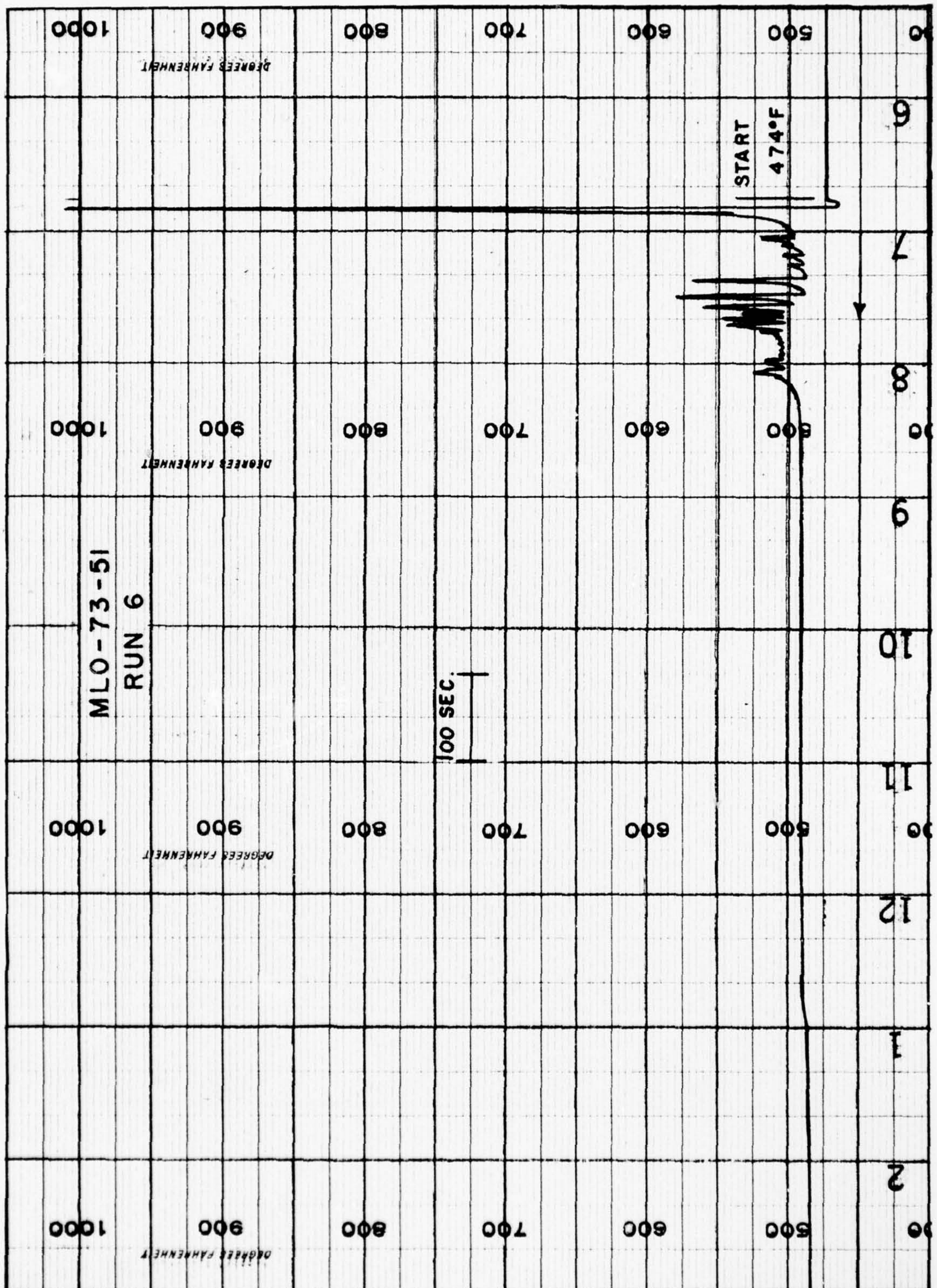

FIGURE 65. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 6.

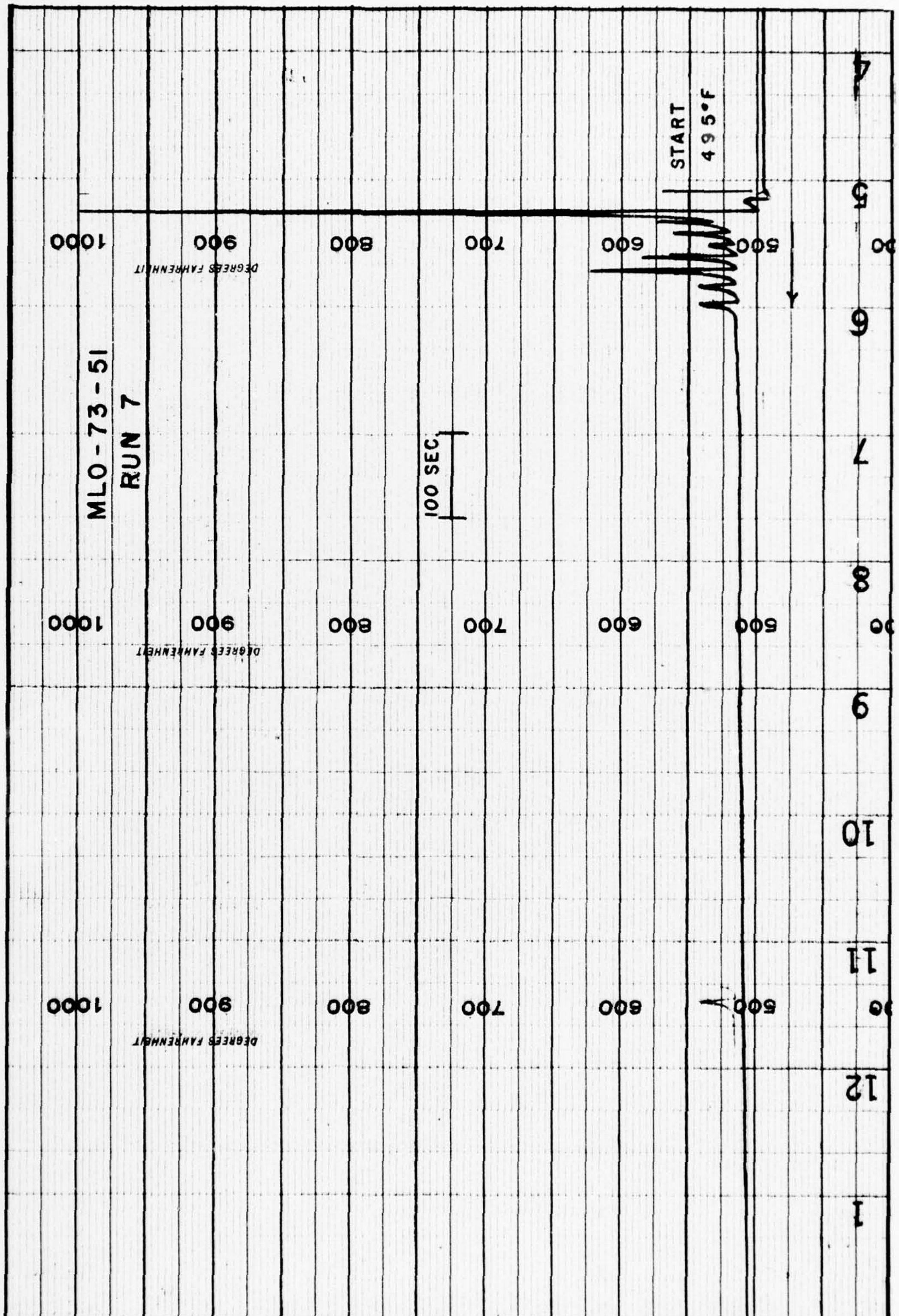

FIGURE 66. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 7.

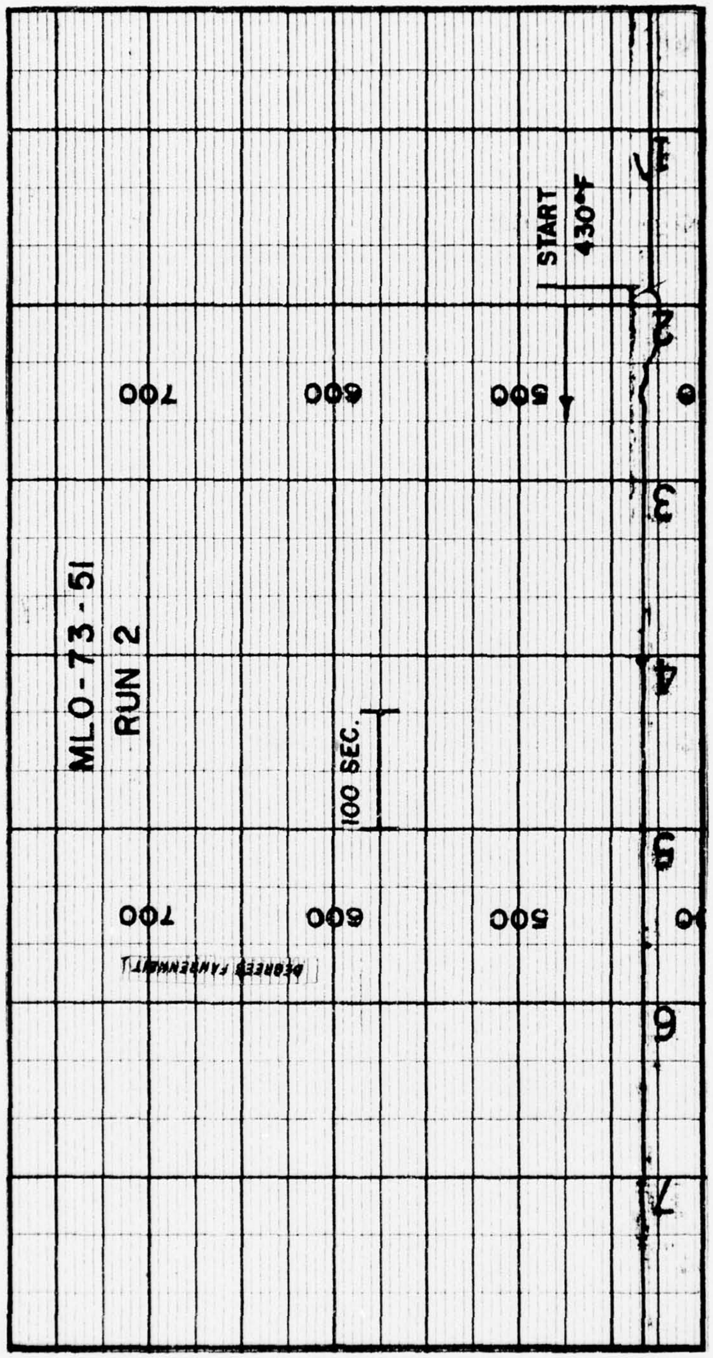

FIGURE 67. MLO-73-51. REACTION THRESHOLD TEMPERATURE. RUN 2.

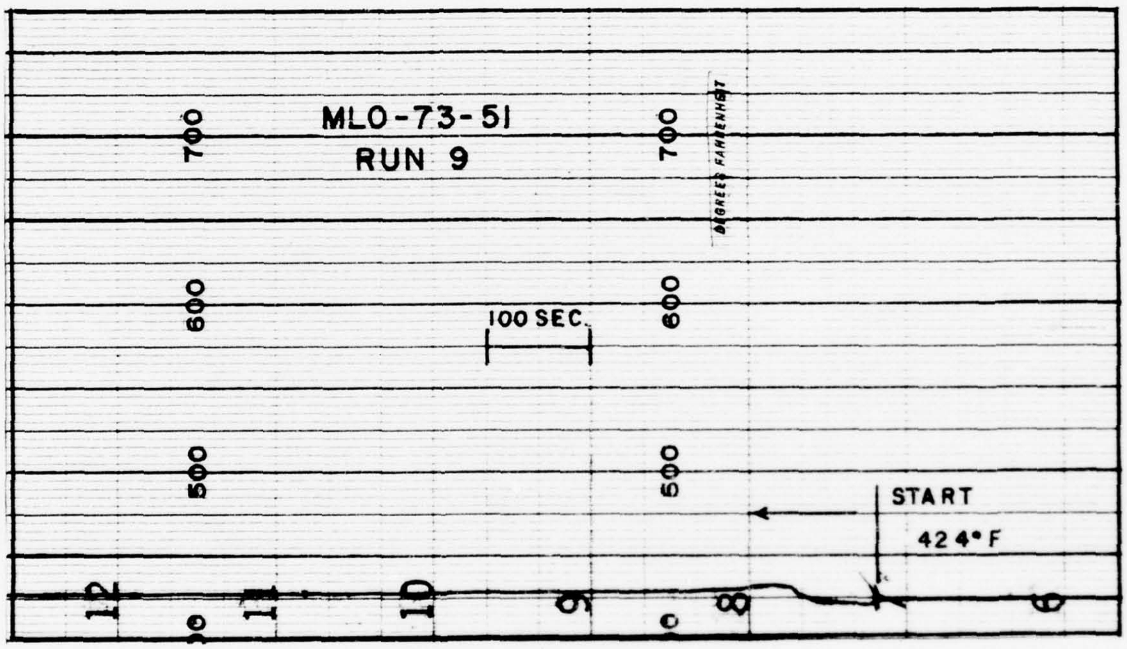

FIGURE 68. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 9.

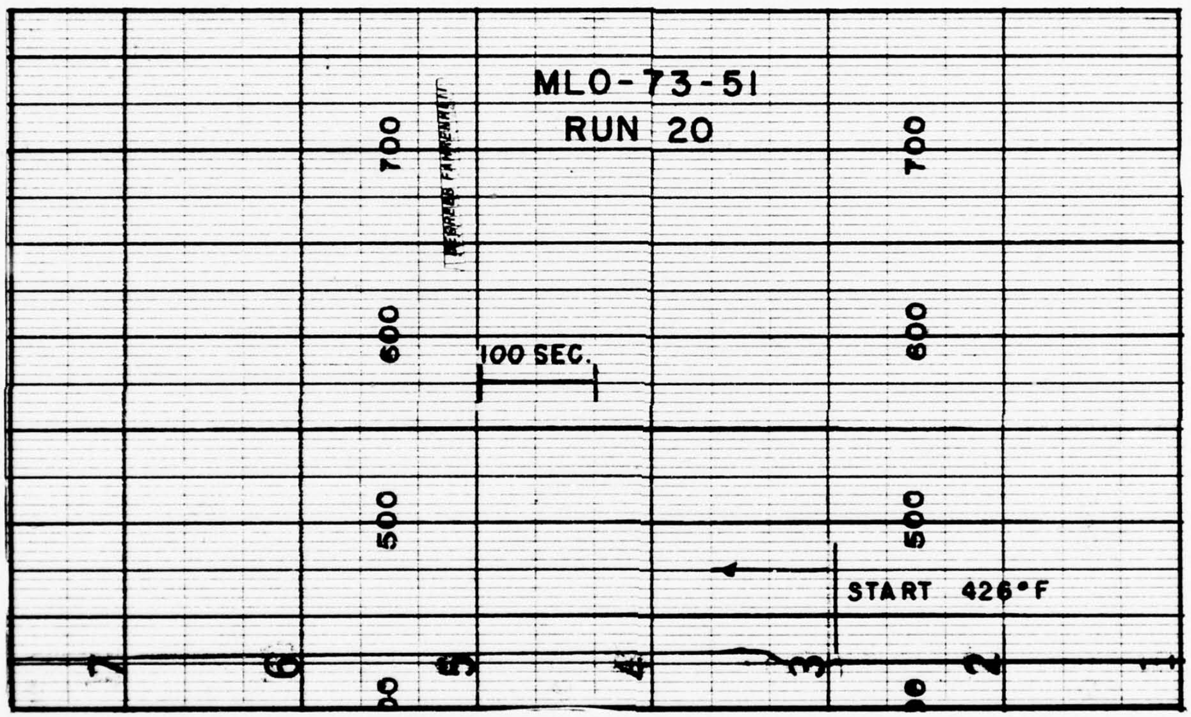

FIGURE 69. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 20.

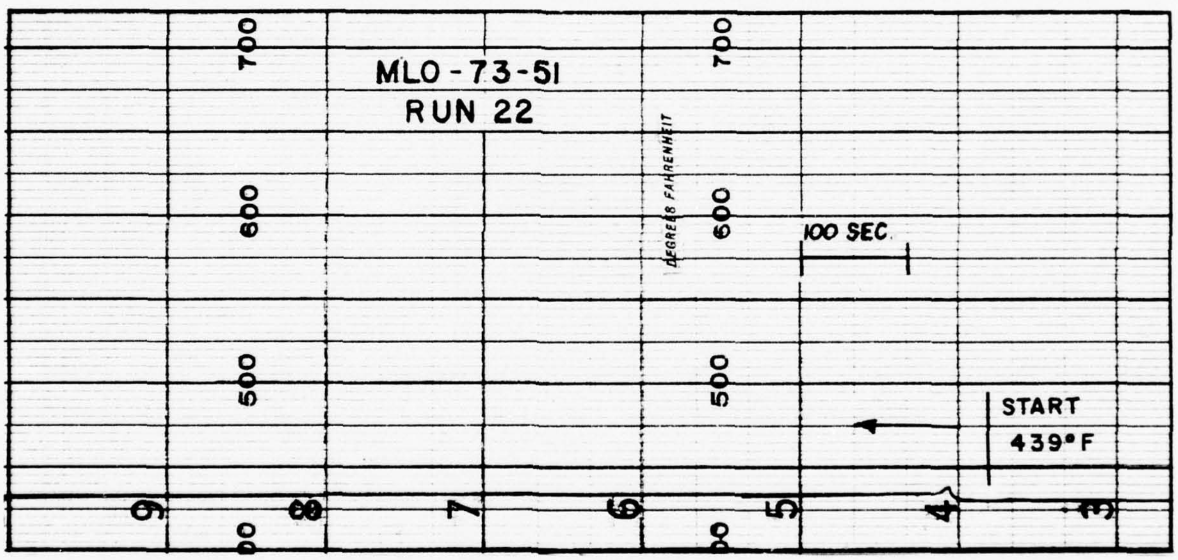

FIGURE 70. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 22.

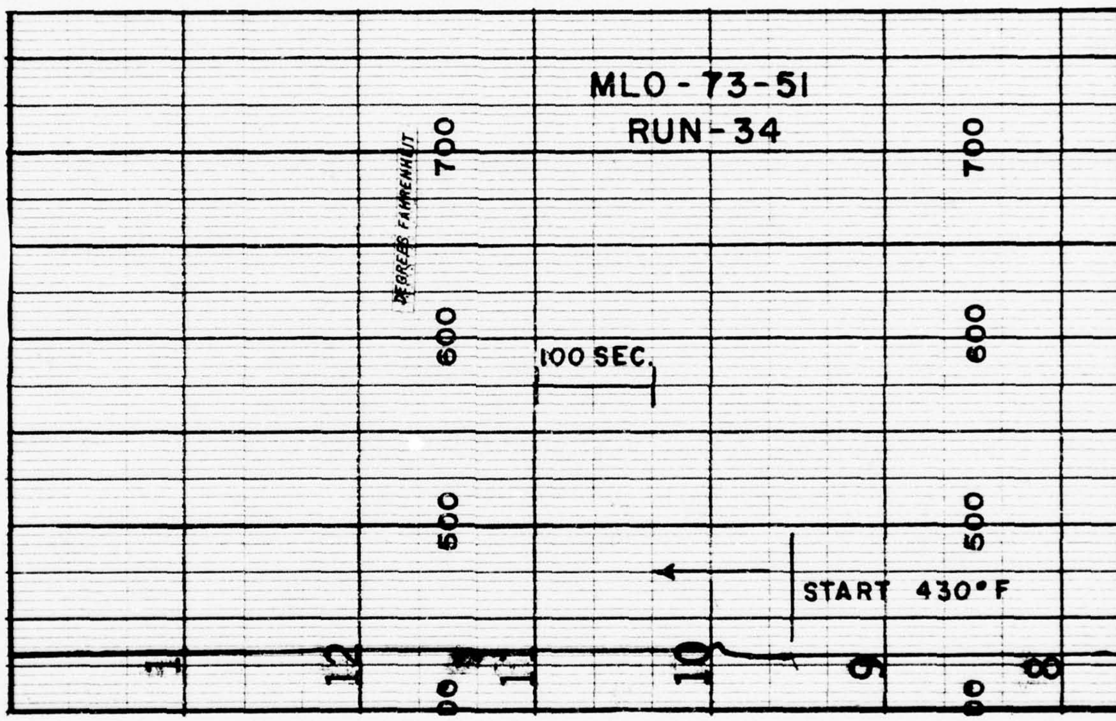

FIGURE 71. MLO-73-51. REACTION THRESHOLD TEMPERATURE, RUN 34.

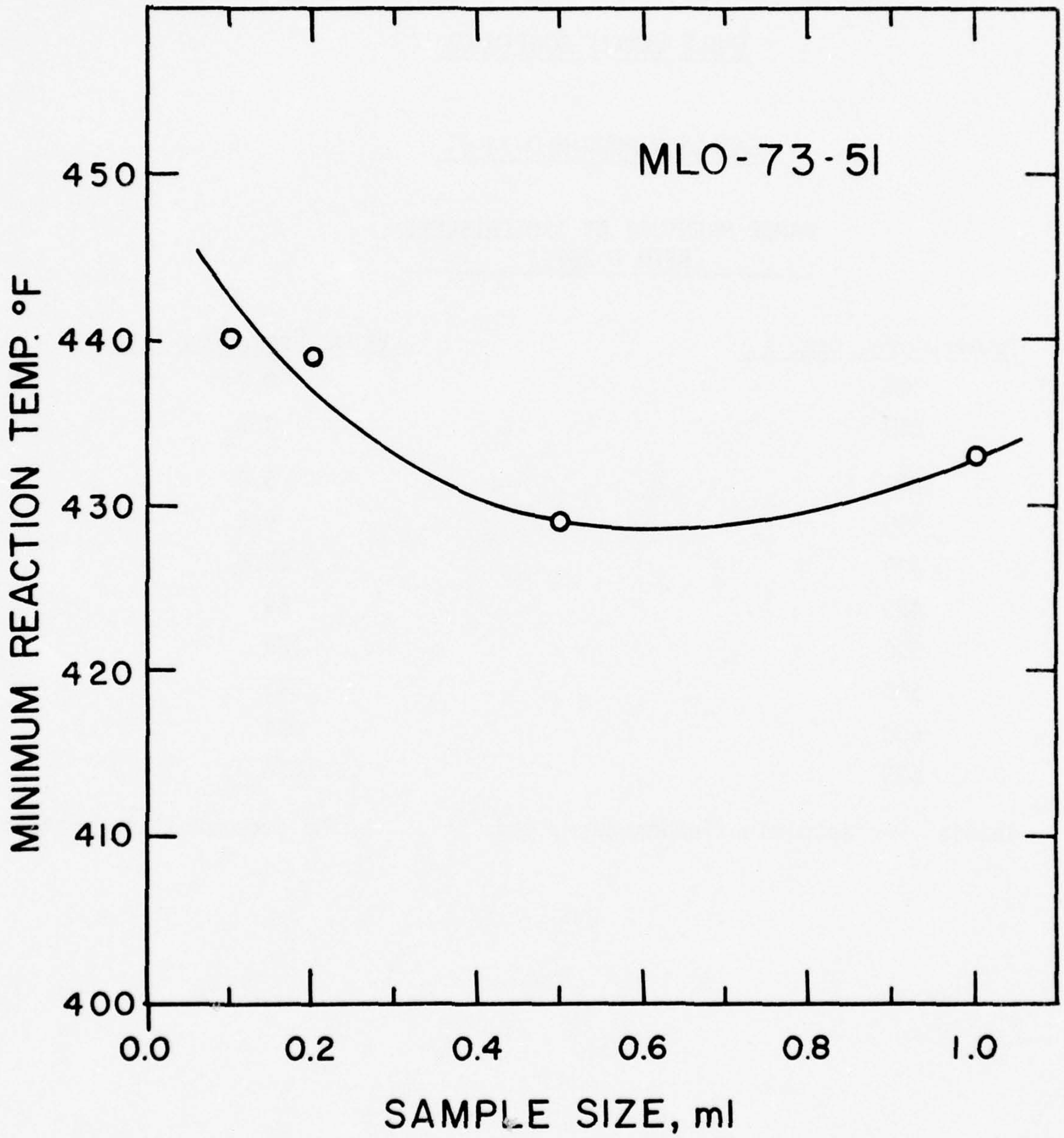

FIGURE 72. MLO-73-51. MINIMUM SPONTANEOUS IGNITION TEMPERATURE

TABLE LXXXIX CONTINUED

SAMPLE NUMBER MLO-73-51

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Vapor Pressure, Torr
200	0.2
250	0.8_5
300	3.0
350	9.5
400	25.5
450	59
500	125
550	265
600	495
625	660
Initial Decomposition Temperature, deg. F.	No decomposition observed

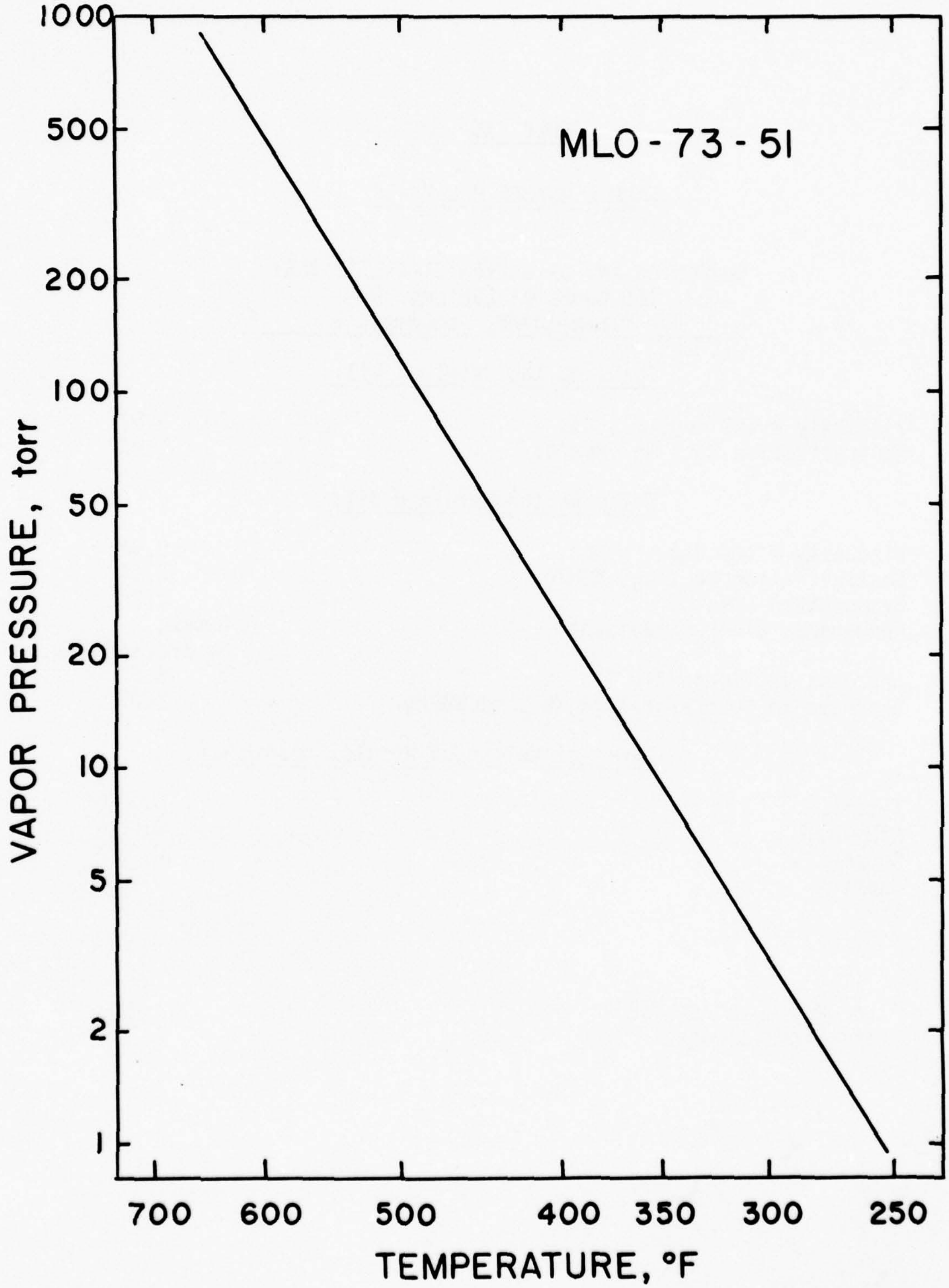

FIGURE 73. MLO-73-51. VAPOR PRESSURE

TABLE XC

SAMPLE NUMBER MLO-73-56

CORROSION AND OXIDATION STABILITY TEST
168 Hours at 250 deg. F.
Per MIL-H-83306, Amendment 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	9.59
Neutralization No., mg. KOH/g.	0.08

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	9.94
Neutralization No., mg. KOH/g.	0.01
Evaporation Loss, %	1.2
Appearance after oxidation:	Brown, No precipitate
Increase in Viscosity, %	3.6
Decrease in Neutralization No., mg.KOH/g.	0.07

Loss of Weight of Metals, mg./sq.cm:

Titanium	0.00
Aluminum	0.00
Copper	0.02 *
Cadmium	0.01 **
Steel	0.00

* Moderate tarnish 2c
** Light tarnish

TABLE XC CONTINUED

SAMPLE NUMBER MLO-73-56

THERMAL STABILITY TEST
168 Hours at 250 deg. F.
Per MIL-H-83306, Amendment 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	9.59
Neutralization No., mg. KOH/g.	0.08

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	9.58
Neutralization No., mg.KOH/g.	0.01
Appearance after oxidation:	Brown, No precipitate
Decrease in Viscosity, %	0.10
Decrease in Neutralization No., mg.KOH/g.	0.07

Loss of Weight of Metals, mg./sq.cm:

Titanium	0.00
Aluminum	0.00
Copper	0.04 *
Cadmium	0.02 **
Steel	0.00

* Slight tarnish 1b
** Moderate tarnish

TABLE XCI

SAMPLE NUMBER MLO-73-62

VAPOR PRESSURE BY ISOTENISCOPE (ASTM D 2879)

Temperature, deg. F.	Torr
200	0.1_8
250	0.8_2
300	3.2
350	10.7
400	30
450	71
500	158
550	340
600	640
625	880

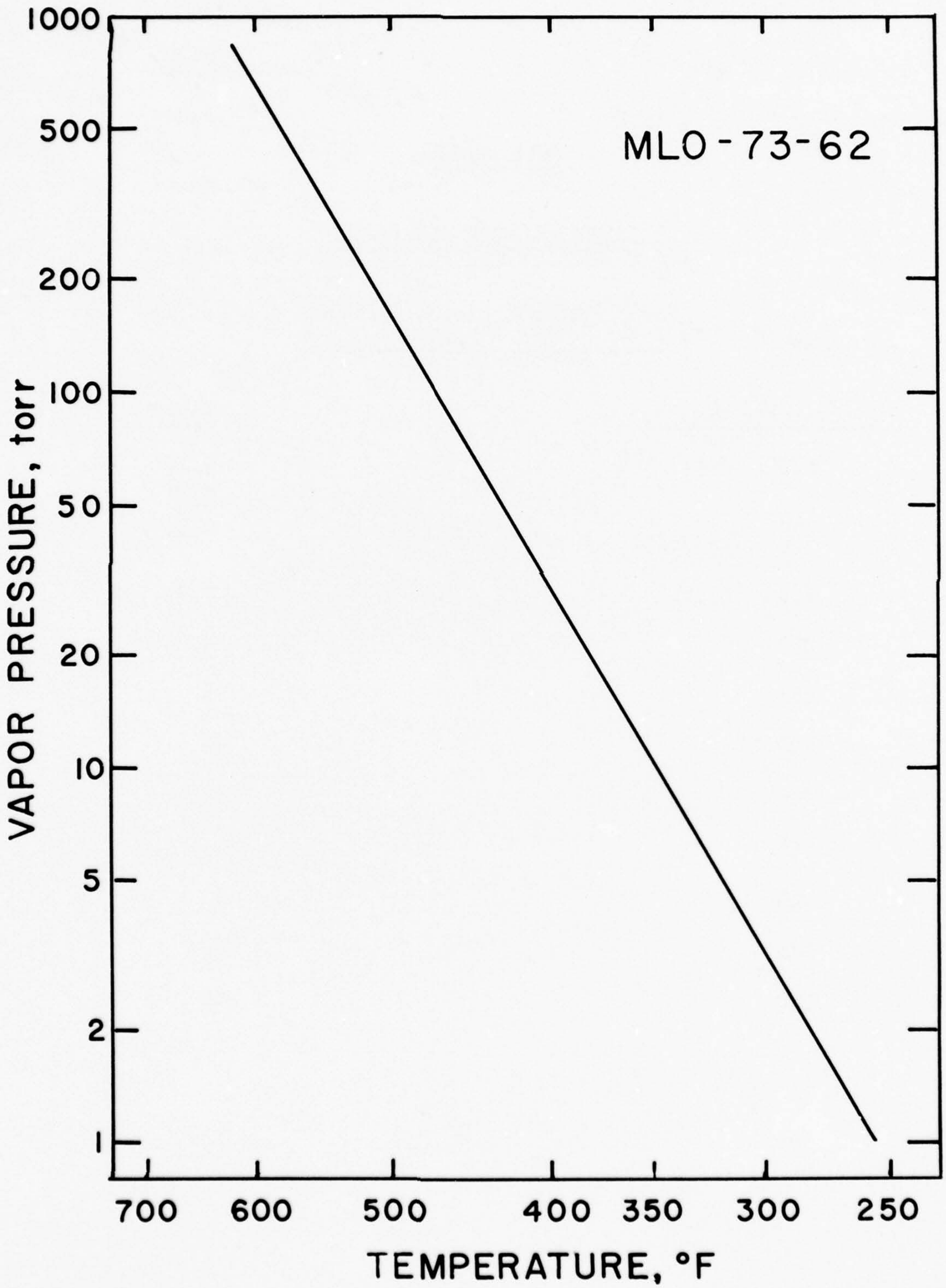

FIGURE 74. MLO-73-62. VAPOR PRESSURE

TABLE XCII

SAMPLE NUMBER MLO-73-63

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
175	0.1_5
200	0.3_3
250	1.4
300	4.8
350	15
400	40
450	92
500	195
550	410
575	560
600	760

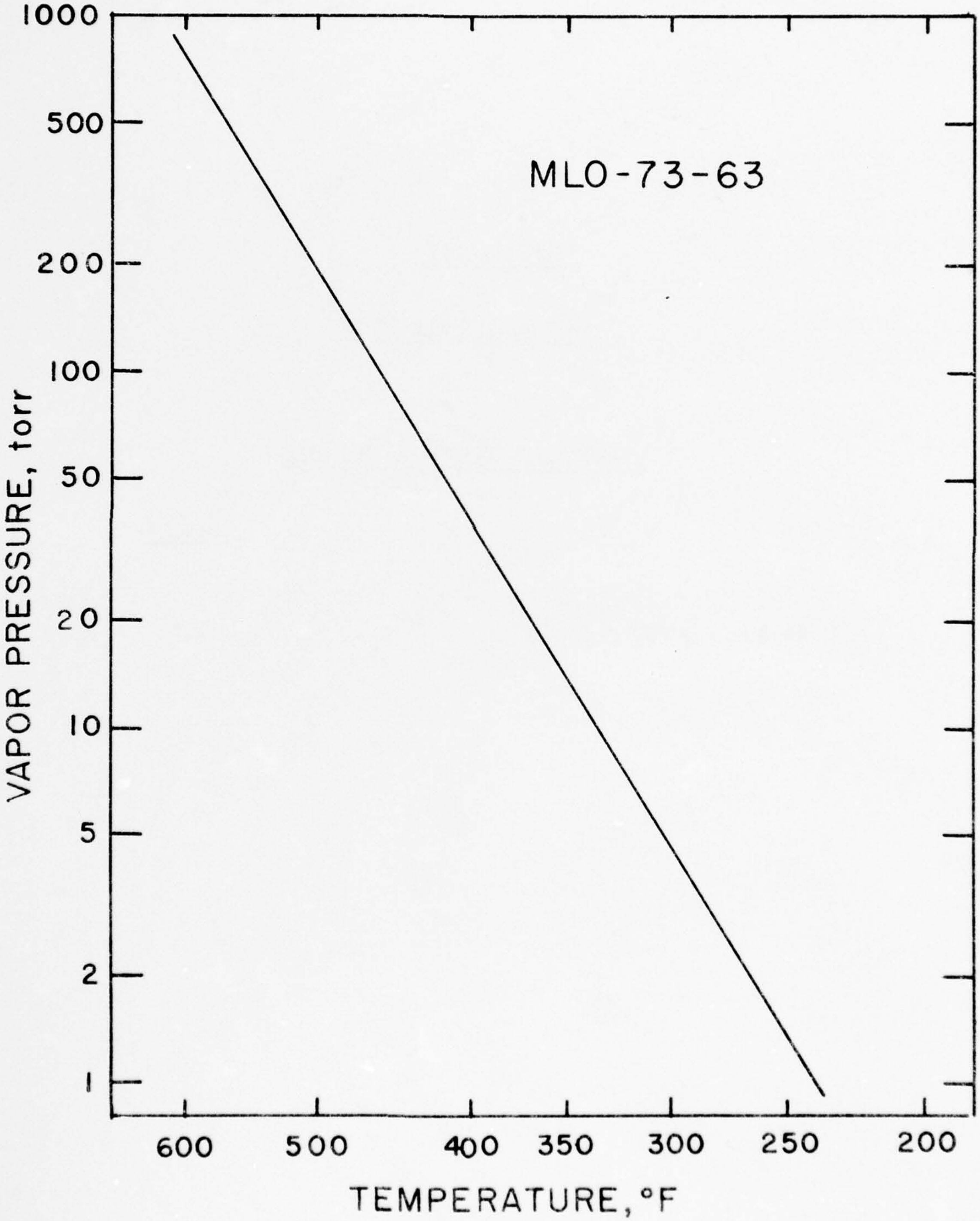

FIGURE 75. MLO-73-63. VAPOR PRESSURE

TABLE XCIII

SAMPLE NUMBER MLO-73-64

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 400 deg. F.	12.7

TABLE XCIV

SAMPLE NUMBER MLO-73-75

CORROSION AND OXIDATION STABILITY TEST
168 hours at 275 deg. F.

Tests on the Original Oil:	
Viscosity @ 100 deg. F., cs.	46.23
Neutralization No., mg.KOH/g.	0.07
Tests on the Oxidized Oil:	
Viscosity @ 100 deg. F., cs.	47.02
Neutralization No., mg.KOH/g.	0.04
Evaporation Loss, %	0.5
Appearance after oxidation:	Straw colored, no precipitate
Increase in Viscosity, %	1.7
Decrease in Neutralization No., mg.KOH/g.	0.03
Loss of Weight of Metals, mg./sq.cm:	
Magnesium	0.00
Aluminum	0.00
Copper	+0.09 *
Cadmium	0.00 **
Steel	0.00 ***

* Corrosion-4A
** Moderate tarnish discoloration
*** Light bronze discoloration

TABLE XCIV CONTINUED

SAMPLE NUMBER MLO-73-75

HYDROLYTIC STABILITY TEST
ASTM D 2619
(48 hours @ 225 deg. F.)

Corrosion:	
1. Change in weight of copper, mg./sq.cm:	+0.001
2. Appearance of copper:	Dark tarnish, 3A
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs:	
a. Original sample	46.23
b. After test	45.89
c. Change, %	-0.7
2. Neutralization No., mg.KOH/g:	
a. Water layer as total acidity	15.08
b. Organic layer	0.08
After test	0.06
Change	-0.02
3. Insoluble material in oil layer, %	0.003

TABLE XCIV CONTINUED

SAMPLE NUMBER MLO-73-75

HYDROLYTIC STABILITY TEST
ASTM D 2619
(48 hours @ 275 deg. F.)

Corrosion:	
1. Change in weight of copper, mg./sq.cm:	0.00
2. Appearance of copper:	Dark tarnish, 3A
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs:	
a. Original sample	46.23
b. After test	46.60
c. Change, %	+0.8
2. Neutralization No., mg.KOH/g:	
a. Water layer as total acidity	20.33
b. Organic layer	0.07
After test	0.06
Change	-0.01
3. Insoluble material in oil layer, %	0.004

TABLE XCIV CONTINUED

SAMPLE NUMBER MLO-73-75

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.4_7
200	1.2_5
250	2.9
300	6.2
350	12.0
400	21.5
450	34.5
475	85
500	170
525	400
550	950
Initial Decomposition Temperature, deg. F.	454

Note: The sample turned brown in color at about 525 deg. F.

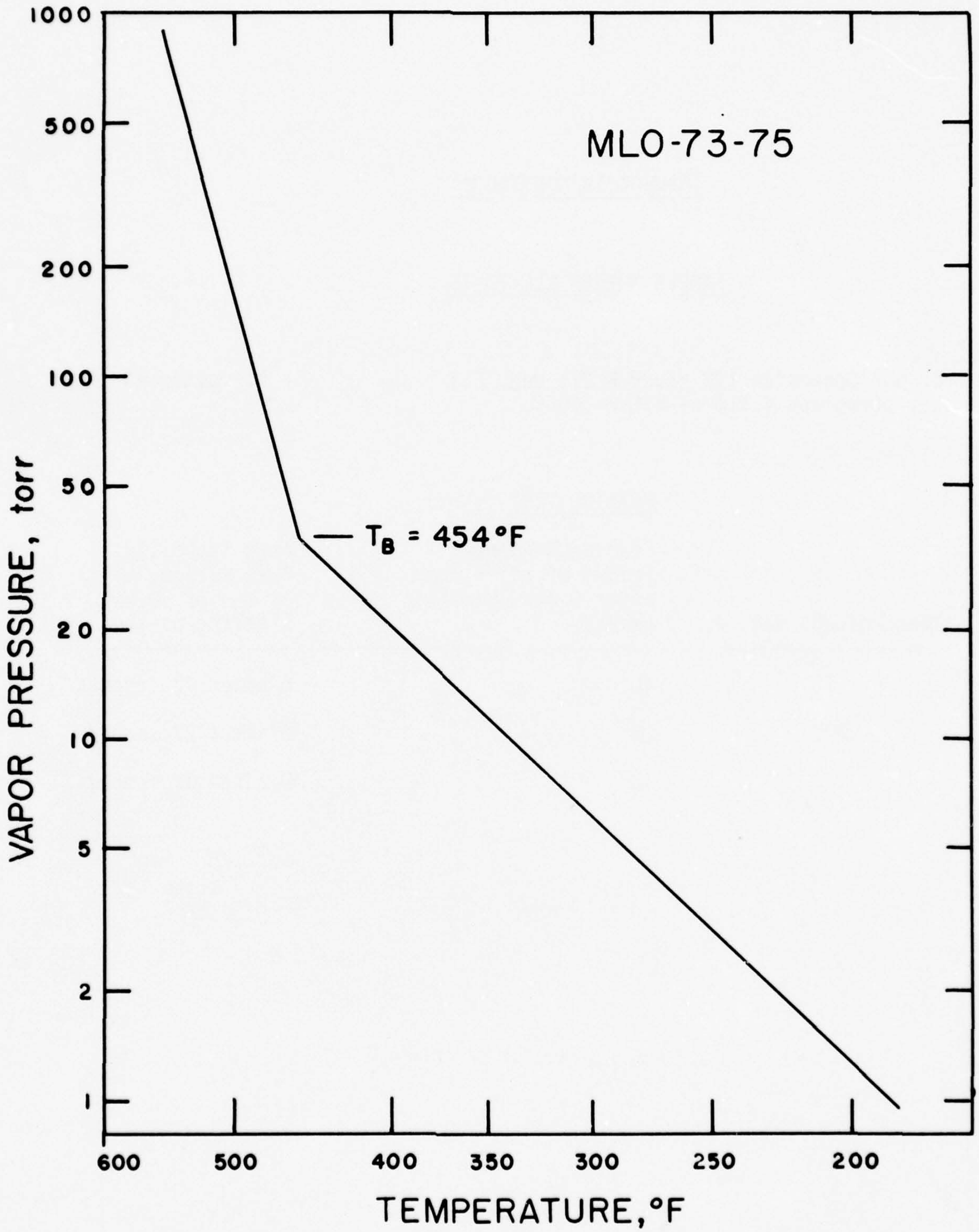

FIGURE 76. MLO-73-75. VAPOR PRESSURE

TABLE XCIV CONTINUED

SAMPLE NUMBER MLO-73-75

Copper Corrosion (72 hours @ 275 deg. F.) per paragraph 4.7.6 of MIL-H-5606C	Corrosion-4A

FOAMING TEST

Temperature, deg. F.	Foaming Tendency: Volume of oil + foam after 5 min. blowing period	Foam Stability: Foam Volume, ml. at end of 10 min. settling period
75	40	0 after 42 seconds
200	20	0 after 27 seconds
75	10	0 after 32 seconds

TABLE XCIV CONTINUED

SAMPLE NUMBER MLO-73-75

EVAPORATION TEST - ASTM D 972

	Loss, %
6½ hours @ 275 deg. F.	0.4

TABLE XCV

SAMPLE NUMBER MLO-73-76

CORROSION AND OXIDATION STABILITY TEST PER MIL-H-83282A 168 hrs at 275 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.45
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	15.57
Neutralization No., mg.KOH/g.	0.02
Evaporation Loss, %	1.2
Appearance after oxidation:	Dark straw, No precipitate
Increase in Viscosity, %	0.8
Increase or Decrease in Neutralization No., mg.KOH/g.	0.00

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Copper	-0.01*
Cadmium	-0.01**
Steel	0.00

* Dark tarnish 3a
** Light tarnish

TABLE XCV CONTINUED

SAMPLE NUMBER MLO-73-76

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs at 300 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.45
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	15.67
Neutralization No., KOH/g.	0.09
Evaporation Loss, %	1.6
Appearance after oxidation:	Dark brown, No precipitate
Increase in Viscosity, %	1.4
Increase in Neutralization No., mg.KOH/g.	0.07

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Copper	+0.01 *
Cadmium	-0.01 **
Steel	0.00

* Dark tarnish 3a
** Light tarnish

TABLE XCV CONTINUED

SAMPLE NUMBER MLO-73-76

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs. at 325 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.45
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	23.41
Neutralization No., mg.KOH/g.	6.81
Evaporation Loss, %	0.8
Appearance after oxidation:	Dark brown, No precipitate
Increase in Viscosity, %	51.5
Increase in Neutralization No., mg.KOH/g.	6.79

Loss of Weight of Metals, mg./sq.cm:

Magnesium	-17.79 *
Aluminum	0.00
Copper	0.00 **
Cadmium	-9.89 ***
Steel	0.00 ****

*   Corrosion, grey and pitted
**   Dark tarnish 3a
*** Corrosion, pitted and etched
**** Brown

TABLE XCV CONTINUED

SAMPLE NUMBER MLO-73-76

CORROSION AND OXIDATION STABILITY TEST
72 hours @ 347 deg. F., per MIL-L-7808G, Amend. 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.53
Neutralization No., mg.KOH/g.	0.01

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	49.40
Neutralization No., mg.KOH/g.	8.37
Evaporation Loss, %	1.1
Appearance after oxidation	Dark brown, no precipitate
Increase in Viscosity, %	218
Increase in Neutralization No., mg.KOH/g.	8.36

Loss of Weight of Metals, mg./sq.cm:

Magnesium	-0.15 *
Aluminum	0.00
Copper	-0.01 **
Silver	-0.01 ***
Steel	0.00 ****

* A few tiny corrosion pits
** Dark tarnish-3A
*** Dark tarnish and light gray discoloration
**** Light olive green and purple discoloration

TABLE XCV CONTINUED

SAMPLE NUMBER MLO 73-76

HYDROLYTIC STABILITY
ASTM D 2619
(48 hours @ 200 deg. F.

Corrosion:	
1. Change in weight of copper, mg./sq.cm:	0.0
2. Appearance of copper	Slight tarnish 1B
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs.	
a. Original sample	15.44
b. After test	15.45
c. Change, %	+0.06
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	2.24
b. Organic layer	0.10
After test	0.03
Change	-0.07
3. Insoluble material in oil layer, %	0.001

TABLE XCV CONTINUED

SAMPLE NUMBER MLO 73-76

HYDROLYTIC STABILITY

ASTM D 2619

(48 hours @ 200 deg. F.)

MODIFICATION: 5% WATER

Corrosion:		
1.	Change in weight of copper, mg./sq.cm:	0.0
2.	Appearance of copper	Slight tarnish 1B
Resistance to Hydrolysis:		
1.	Viscosity @ 100 deg. F., cs.	
	a. Original sample	15.44
	b. After test	15.45
	c. Change, %	+0.06
2.	Neutralization No., mg.KOH/g.	
	a. Water layer as total acidity	2.63
	b. Organic layer	0.10
	After test	0.09
	Change	-0.01
3.	Insoluble material in oil layer, %	0.005

TABLE XCV CONTINUED

SAMPLE NUMBER MLO-73-76

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.3_2
200	0.9_4
250	2.6
300	5.6
350	12
400	23
450	40
500	66
550	109
600	194
650	500
675	700
Initial Decomposition Temperature, deg. F.	581

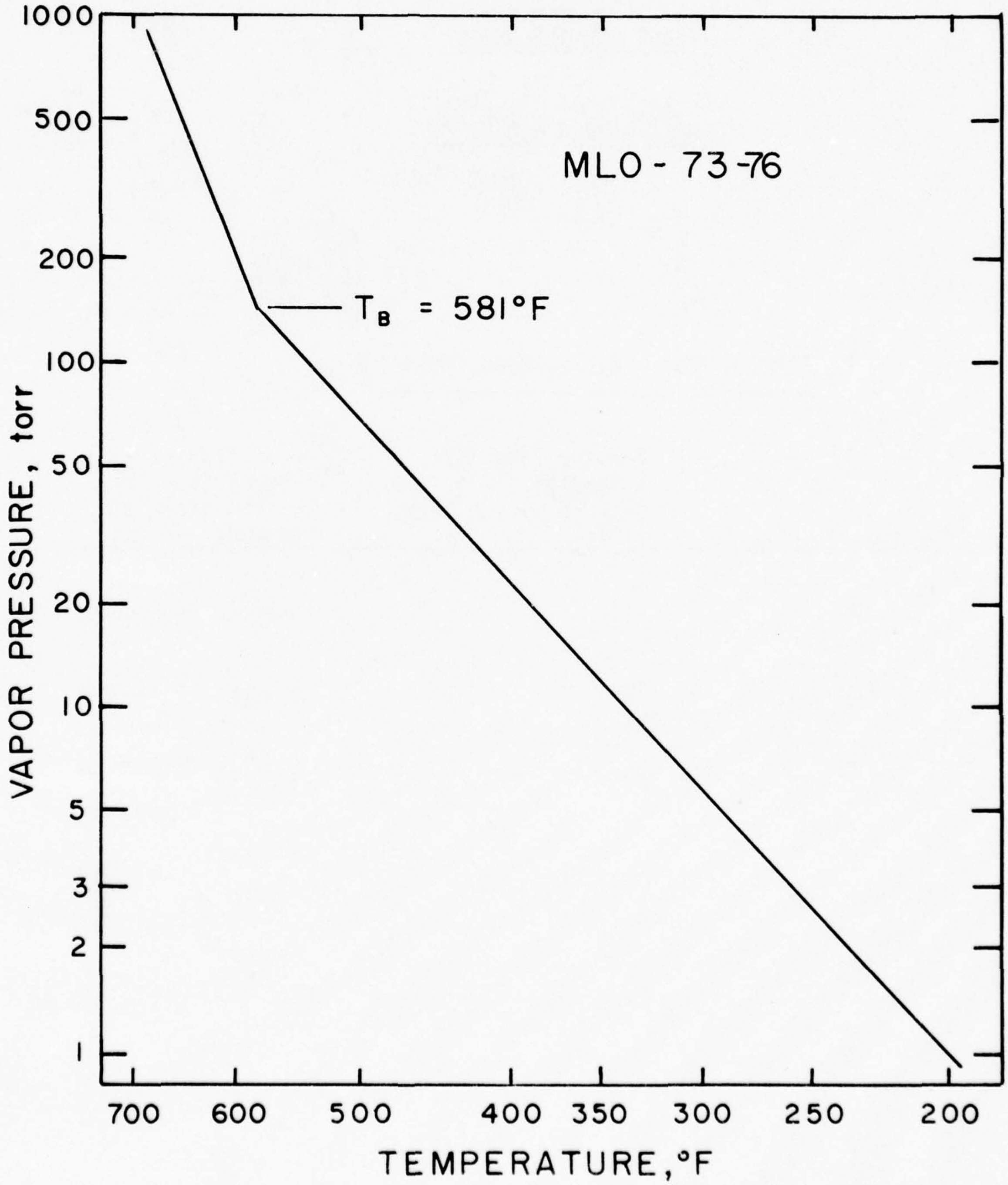

FIGURE 77. MLO-73-76. VAPOR PRESSURE

TABLE XCV CONTINUED

SAMPLE NUMBER MLO-73-76

FOAMING TEST - MIL-L-7808G, AMEND. 2

Temperature, deg. F.	Foaming Tendency: Volume of oil + foam after 5 min. blowing period	Foam Stability: Foam Volume, ml. at end of 10 min. settling period
75	25	0 after 18 seconds
200	20	0 after 11 seconds
75	30	0 after 15 seconds

TABLE XCVI

SAMPLE NUMBER MLO-73-93

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs at 275 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	16.09
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	16.45
Neutralization No., mg.KOH/g.	0.20
Evaporation Loss, %	1.0
Appearance after oxidation:	Dark brown, small amount of Light grey precipitate
Increase in Viscosity, %	2.2
Increase in Neutralization No., mg.KOH/g.	0.18

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Copper	-0.07*
Cadmium	-0.08**
Steel	0.00***

* Dark tarnish 3a
** Moderate tarnish & etching
*** Purple & Light brown discoloration

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO-73-93

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A

168 hrs. at 300 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	16.09
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	27.40
Neutralization No., mg.KOH/g.	4.92
Evaporation Loss, %	2.0
Appearance after oxidation:	Dark brown, Slight Light grey precipitate
Increase in Viscosity, %	70.3
Increase in Neutralization No., mg.KOH/g.	4.90

Loss of Weight of Metals, mg./sq.cm:

Magnesium	-12.27 *
Aluminum	0.00 **
Copper	-0.28 ***
Cadmium	-69.31 ****
Steel	0.00 *****

*	Pitted, etched and dark grey
**	Faint multicolor
***	Moderate tarnish 2c and etched
****	Corrosion, etched, eroded and grey
*****	Multicolor

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO-73-93

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A

168 hrs. at 325 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	16.09
Neutralization No., mg.KOH/g.	0.02

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	39.84
Neutralization No., mg.KOH/g.	7.36
Evaporation Loss, %	2.5
Appearance after oxidation:	Dark brown, Slight brown precipitate
Increase in Viscosity, %	147.6
Increase in Neutralization No., mg.KOH/g.	7.34

Loss of Weight of Metals, mg./sq.cm:

Magnesium	-24.10 *
Aluminum	0.00
Copper	-2.87 **
Cadmium	-49.54 ***
Steel	0.00 ****

* Corrosion, grey and pitted
** Dark tarnish 3b and etched
*** Corrosion, etched and coppertone
**** Multicolor

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO 73-93

HYDROLYTIC STABILITY

ASTM D 2619

(48 hours @ 200 deg. F.

Corrosion:	
1. Change in weight of copper, mg./sq.cm:	0.0
2. Appearance of copper	Slight tarnish 1B
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs.	
a. Original sample	16.02
b. After test	16.04
c. Change, %	+0.1
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	1.56
b. Organic layer	0.04
After test	0.05
Change	+0.01
3. Insoluble material in oil layer, %	0.001

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO 73-93

HYDROLYTIC STABILITY
ASTM D 2619
(48 hours @ 200 deg. F.
MODIFICATION: 5% WATER

Corrosion:	
1. Change in weight of copper, mg./sq.cm:	0.0
2. Appearance of copper	Slight tarnish 1B
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs.	
a. Original sample	16.02
b. After test	16.00
c. Change, %	-0.1
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	1.17
b. Organic layer	0.04
After test	0.11
Change	+0.07
3. Insoluble material in oil layer, %	0.002

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO-73-93

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.4_8
200	1.3
250	3.1
300	6.7
350	13.3
400	23.8
450	39
500	67
550	97
600	210
650	495
675	685
Initial Decomposition Temperature, deg. F.	561

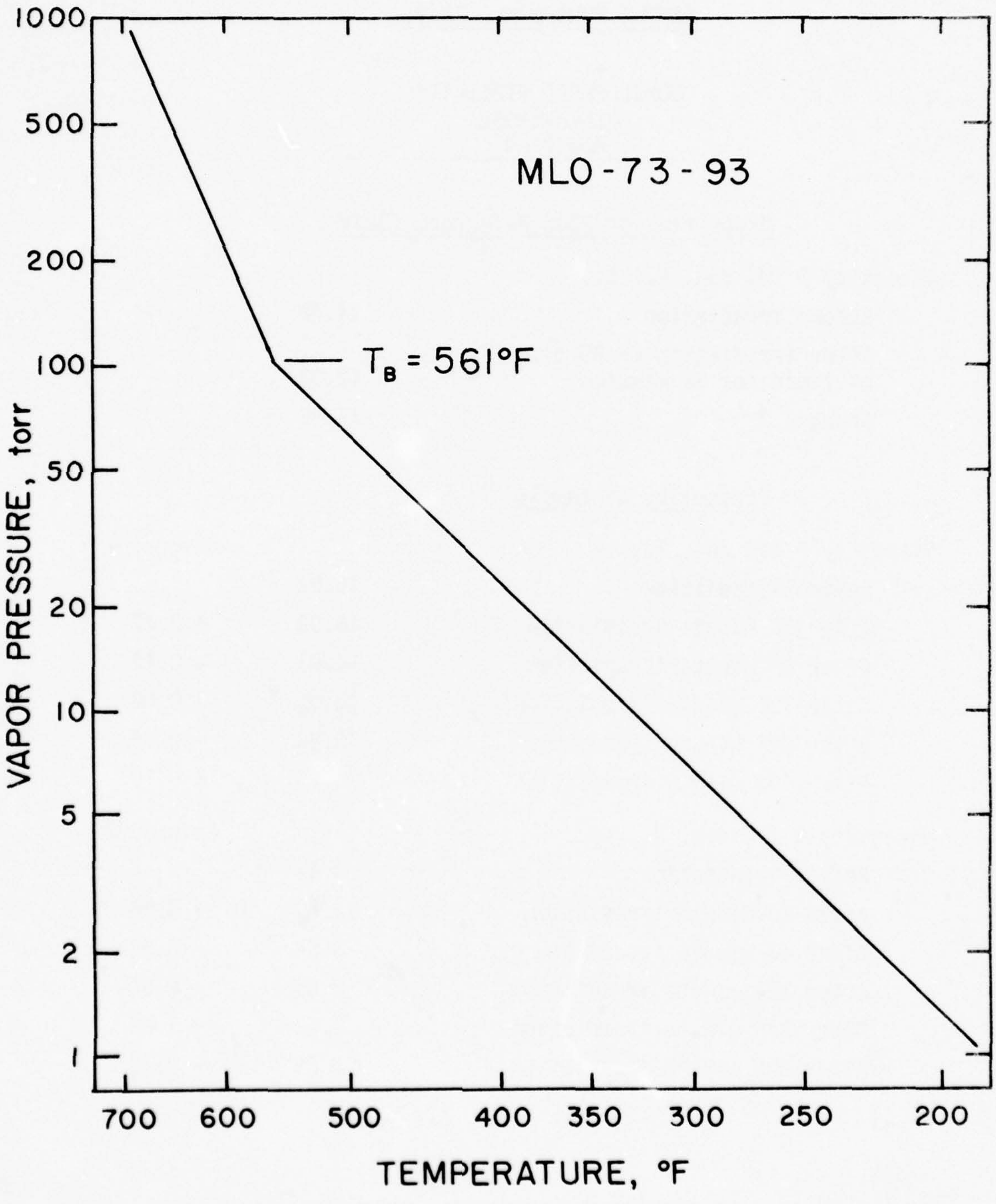

FIGURE 78. MLO-73-93. VAPOR PRESSURE

TABLE XCVI CONTINUED

SAMPLE NUMBER MLO-73-93

SONIC SHEAR STABILITY
MIL-H-5606c
Modified

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
Before irradiation	14.42
After irradiation of 30 ml. of fluid for 30 minutes	12.32
Change, %	-14.56

Properties of Sample

Viscosity @ 100 deg. F., cs.		Change, %
Before irradiation	16.03	
After 20 minute irradiation	16.09	+ 0.37
After 60 minute irradiation	16.01	- 0.12
After 120 minute irradiation	16.03	0.00
After 240 minute irradiation	15.94	- 0.56
After 400 minute irradiation	16.15	+ 0.75
Viscosity @ 210 deg. F., cs.		Change, %
Before irradiation	3.67	
After 20 minute irradiation	3.69	+ 0.54
After 60 minute irradiation	3.64	- 0.82
After 120 minute irradiation	3.65	- 0.54
After 240 minute irradiation	3.63	- 1.09
After 400 minute irradiation	3.59	- 2.18

TABLE CXVII

SAMPLE NUMBER MLO-74-14

SONIC SHEAR TEST
Per MIL-H-5606C, Modified
Time: 400 min.

Properties of Reference Fluid 5606C

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	14.46
b. After irradiation of 30 ml. of fluid for 30 minutes	12.35
c. % change	-14.59
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	436.4
b. After irradiation	408.9
c. % change	-6.3
Viscosity @ -65 deg. F., cs:	
a. Before irradiation	2,384
b. After irradiation	1,704
c. % change	-28.5

TABLE CXVII CONTINUED

SAMPLE NUMBER MLO-74-14
CONTINUED

Properties of Sample

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	14.29
b. After irradiation of 30 ml. fluid for 400 min.	9.72
c. % change	-32.0
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	416.5
b. After irradiation	345.3
c. % change	-17.1
Viscosity @ -65 deg. F., cs:	
a. Before irradiation	2,298
b. After irradiation	1,620
c. % change	-29.5
Neutralization No., mg. KOH/g.	
a. Before irradiation	0.01
b. After irradiation	0.04
c. Change, mg. KOH/g.	+0.03

TABLE CXVII CONTINUED

SAMPLE NUMBER MLO-74-14

SONIC SHEAR STABILITY
MIL-H-5606c
Modified

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
Before irradiation	14.42
After irradiation of 30 ml. of fluid for 30 minutes	12.31
Change, %	-14.63

Properties of Sample

Viscosity @ 100 deg. F., cs.		Change, %
Before irradiation	14.29	
After 20 minute irradiation	13.03	- 8.82
After 60 minute irradiation	11.77	-17.63
After 120 minute irradiation	10.83	-24.21
After 240 minute irradiation	9.72	-31.98
After 400 minute irradiation	8.82	-38.28
Viscosity @ 210 deg. F., cs.		Change, %
Before irradiation	5.11	
After 20 minute irradiation	4.59	-10.18
After 60 minute irradiation	4.20	-17.81
After 120 minute irradiation	3.77	-26.22
After 240 minute irradiation	3.32	-35.03
After 400 minute irradiation	3.06	-40.12

TABLE CXVIII

SAMPLE NUMBER MLO-74-15

SONIC SHEAR TEST
Per MIL-H-5606C, Modified
Time: 400 min.

Properties of Reference Fluid 5606C

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	14.46
b. After irradiation of 30 ml. of fluid for 30 minutes	12.35
c. % change	-14.59
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	436.4
b. After irradiation	408.9
c. % change	-6.3
Viscosity @ -65 deg F., cs:	
a. Before irradiation	2,384
b. After irradiation	1,704
c. % change	-28.5

TABLE CXVIII CONTINUED

SAMPLE NUMBER MLO-74-15

CONTINUED

Properties of Sample

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	14.18
b. After irradiation of 30 ml. fluid for 400 min.	9.46
c. % change	-33.39
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	407.0
b. After irradiation	330.3
c. % change	-18.8
Viscosity @ -65 deg. F., cs:	
a. Before irradiation	2,125
b. After irradiation	1,469
c. % change	-30.9
Neutralization No., mg. KOH/g.	
a. Before irradiation	0.01
b. After irradiation	0.04
c. Change, mg. KOH/g.	+0.03

TABLE CXVIII CONTINUED

5606 Reference Fluid

SONIC SHEAR STABILITY
MIL-H-5606c
Modified

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
Before irradiation	14.46
After irradiation of 30 ml. of fluid for 30 minutes	12.33
Change, %	-14.73

Properties of Sample

Viscosity @ 100 deg. F., cs.		Change, %
Before irradiation	14.46	
After 20 minute irradiation	12.74	-11.89
After 60 minute irradiation	11.78	-18.53
After 120 minute irradiation	11.04	-23.65
After 240 minute irradiation	10.19	-29.53
After 400 minute irradiation	9.21	-33.20
Viscosity @ 210 deg. F., cs.		Change, %
Before irradiation	5.10	
After 20 minute irradiation	4.46	-12.55
After 60 minute irradiation	4.11	-19.41
After 120 minute irradiation	3.84	-24.71
After 240 minute irradiation	3.52	-30.98
After 400 minute irradiation	3.33	-34.71

TABLE CXVIII CONTINUED

SAMPLE NUMBER MLO-74-15

SONIC SHEAR STABILITY
MIL-H-5606c
Modified

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
Before irradiation	14.42
After irradiation of 30 ml. of fluid for 30 minutes	12.32
Change, %	-14.56

Properties of Sample

Viscosity @ 100 deg. F., cs.		Change, %
Before irradiation	14.21	
After 20 minute irradiation	13.00	- 8.51
After 60 minute irradiation	11.69	-17.73
After 120 minute irradiation	10.80	-24.00
After 240 minute irradiation	9.45	-33.50
After 400 minute irradiation	8.60	-39.48
Viscosity @ 210 deg. F., cs.		Change, %
Before irradiation	5.14	
After 20 minute irradiation	4.71	- 8.37
After 60 minute irradiation	4.24	-17.51
After 120 minute irradiation	3.85	-25.10
After 240 minute irradiation	3.40	-33.85
After 400 minute irradiation	3.05	-40.66

TABLE CXIX

SAMPLE NUMBER MLO-74-19

SONIC SHEAR STABILITY
MIL-H-5606C
Amend. 1

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
a. Before irradiation	14.42
b. After irradiation of 30 ml. of fluid for 30 min.	12.32
c. Per Cent Change	-14.56
Viscosity @ -40 deg. F., cs.	
a. Before irradiation	496.9
b. After irradiation of 30 ml. of fluid for 30 min.	435.8
c. Per Cent Change	-12.30

Properties of Sample

Viscosity @ 100 deg. F., cs.	
a. Before irradiation	16.88
b. After irradiation of 30 ml. of fluid for 30 min.	16.74
c. Per Cent Change	-0.83
Viscosity @ -40 deg. F., cs.	
a. Before irradiation	144.0
b. After irradiation of 30 ml. of fluid for 30 min.	1140.5
c. Per Cent Change	-0.31
Neutralization No., mg.KOH/g.	
a. Before irradiation	0.08
b. After irradiation of 30 ml. of fluid for 30 min.	0.35
c. Change, mg.KOH/g.	+0.27

TABLE CXIX CONTINUED

SAMPLE NUMBER MLO-74-19

Viscosity @ -65 deg. F., cs.	4,917.9
Viscosity @ 100 deg. F., cs.	16.88
Viscosity @ 400 deg. F., cs.	1.49
Evaporation Loss, % (6½ hours @ 400 deg. F.)	9.5

TABLE C

SAMPLE NUMBER MLO-74-20

SONIC SHEAR STABILITY
MIL-H-5606C
Amend. 1

Properties of 5606 Reference Fluid

Viscosity @ 100 deg. F., cs.	
a. Before irradiation	14.42
b. After irradiation of 30 ml. of fluid for 30 min.	12.32
c. Per Cent Change	-14.56
Viscosity @ -40 deg. F., cs.	
a. Before irradiation	496.9
b. After irradiation of 30 ml. of fluid for 30 min.	435.8
c. Per Cent Change	-12.30

Properties of Sample

Viscosity @ 100 deg. F., cs.	
a. Before irradiation	14.65
b. After irradiation of 30 ml. of fluid for 30 min.	14.56
c. Per Cent Change	-0.61
Viscosity @ -40 deg. F., cs.	
a. Before irradiation	827.0
b. After irradiation of 30 ml. of fluid for 30 min.	820.0
c. Per Cent Change	-0.85
Neutralization No., mg.KOH/g.	
a. Before irradiation	0.05
b. After irradiation of 30 ml. of fluid for 30 min.	0.84
c. Change, mg.KOH/g.	+0.79

TABLE C CONTINUED

SAMPLE NUMBER MLO-74-20

LINEAR FLAME PROPAGATION RATE

RUN NO.	FLAME ADVANCE RATE, cm/sec
1	0.303
2	0.318
3	0.308
4	0.331
5	0.309
6	0.300
7	0.303
8	0.299
9	0.335
10	0.284
Average	0.309
Standard Deviation	0.015
Probable Error	0.010

TABLE C CONTINUED

SAMPLE NUMBER MLO-74-20

Viscosity @ -65 deg. F., cs.	3,367.5
Viscosity @ 100 deg. F., cs.	14.65
Viscosity @ 400 deg. F., cs.	1.42
Evaporation Loss, % (6½ hours @ 400 deg. F.)	7.6

TABLE CI

SAMPLE NUMBER MLO-74-21

ASTM D 2596
RUN 1

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
40 *	0.343	
50	1.568	10.267
63	1.771	12.343
80	1.974	15.238
100	2.002	20.229
126	2.30	24.000
160	WELD	
		82.077

* Last non-seizure load

Calculation:

Total of corrected loads	82.0
Total of line of compensation loads	118.0
Total A	200.0

Load Wear Index $= \frac{200.0}{10} = 20.0$

TABLE CI CONTINUED

SAMPLE NUMBER MLO-74-21

ASTM D 2596
RUN 2

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
40 *	0.336	
50	1.771	9.090
63	1.848	11.829
80	1.932	15.569
100	2.023	20.019
126	2.45	22.530
160	WELD	
		79.037

* Last non-seizure load

Calculation:

Total of corrected loads	79.0
Total of line of compensation loads	118.0
Total A	197.0

Load Wear Index $= \frac{197.0}{10} = 19.7$

TABLE CII

SAMPLE NUMBER MLO-74-22

ASTM D 2596
RUN 1

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
80 *	0.427	
100	1.890	21.428
126	2.12	26.037
160	WELD	
		47.465

* Last non-seizure load

Calculation:

Total of corrected loads	47.4
Total of line of compensation loads	290.0
Total A	337.4

Load Wear Index $= \frac{337.4}{10} = 33.7$

TABLE CII CONTINUED

SAMPLE NUMBER MLO-74-22

ASTM D 2596
RUN 2

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
80 *	0.420	
100	1.799	22.512
126	2.12	26.037
160	WELD	
		48.549

* Last non-seizure load

Calculation:

Total of corrected loads	48.5
Total of line of compensation loads	290.0
Total A	338.5

Load Wear Index = $\frac{338.5}{10}$ = 33.8

TABLE CIII

SAMPLE NUMBER MLO-74-23

ASTM D 2596
RUN 1

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
24 *	0.294	
32	0.336	26.398
40	0.364	32.857
50	0.483	33.333
63	1.099	19.890
80	1.309	22.979
100	1.491	27.162
126	1.645	33.556
160	1.897	39.957
200	2.35	43.489
250	WELD	
		279.621

* Last non-seizure load

Calculation:

Total of corrected loads	279.6
Total of line of compensation loads	21.6
Total A	301.2

Load Wear Index $= \frac{301.2}{10} = 30.1$

TABLE CIII CONTINUED

SAMPLE NUMBER MLO-74-23

ASTM D 2596
RUN 2

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
24 *	0.294	
32	0.336	26.398
40	0.392	30.510
50	0.497	32.394
63	1.281	17.064
80	1.330	22.616
100	1.512	26.785
126	1.680	32.857
160	1.904	39.810
200	2.38	42.941
250	WELD	
		271.375

* Last non-seizure load

Calculation:

Total of corrected loads	271.3
Total of line of compensation loads	21.6
Total A	292.9

Load Wear Index $= \frac{292.9}{10} = 29.3$

TABLE CIV

SAMPLE NUMBER MLO-74-24

ASTM D 2596
RUN 1

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
100 *	0.469	
126	0.546	101.098
160	3.07	24.690
200	WELD	
		125.788

* Last non-seizure load

Calculation:

Total of corrected loads	125.7
Total of line of compensation loads	364.4
Total A	490.1

$$\text{Load Wear Index} = \frac{490.1}{10} = 49.0$$

TABLE CIV CONTINUED

SAMPLE NUMBER MLO-74-24

ASTM D 2596
RUN 2

Applied Load, kg.	Average Diameter, mm.	Corrected Load, kg.
100 *	0.476	
126	0.532	103.759
160	2.98	25.436
200	WELD	
		129.195

* Last non-seizure load

Calculation:

Total of corrected loads	129.1
Total of line of compensation loads	364.4
Total A	493.5

Load Wear Index $= \frac{493.5}{10} = 49.4$

TABLE CV

SAMPLE NUMBER MLO-74-36

PARTICLE COUNT PER MIL-H-83282

Range, Microns	Particles/100 ml.
5 - 15	32,713
16 - 25	1,590
26 - 50	856
51 - 100	0
100 and greater	0
Fibers:	
100 and greater	0
Particle Weight, mg./100 ml.	2.7

TABLE CVI

SAMPLE NUMBER MLO-74-37

PARTICLE COUNT PER MIL-H-83282

Range, Microns	Particles/100 ml.
5 - 15	30,258
16 - 25	4,739
26 - 50	1,094
51 - 100	122
100 and greater	61
Fibers:	
100 and greater	0

Particle Weight, mg./100 ml.	2.3

TABLE CVII

SAMPLE NUMBER MLO-74-41

VAPOR PRESSURE BY ISOTENISCOPE (ASTM D 2879)

Temperature, deg. F.	Torr
150	1.5
200	3.5
250	7.3
300	14
350	25
400	41
450	63
500	92
550	150
600	248
650	410
700	630
750	900
Initial Decomposition Temperature, deg. F.	530

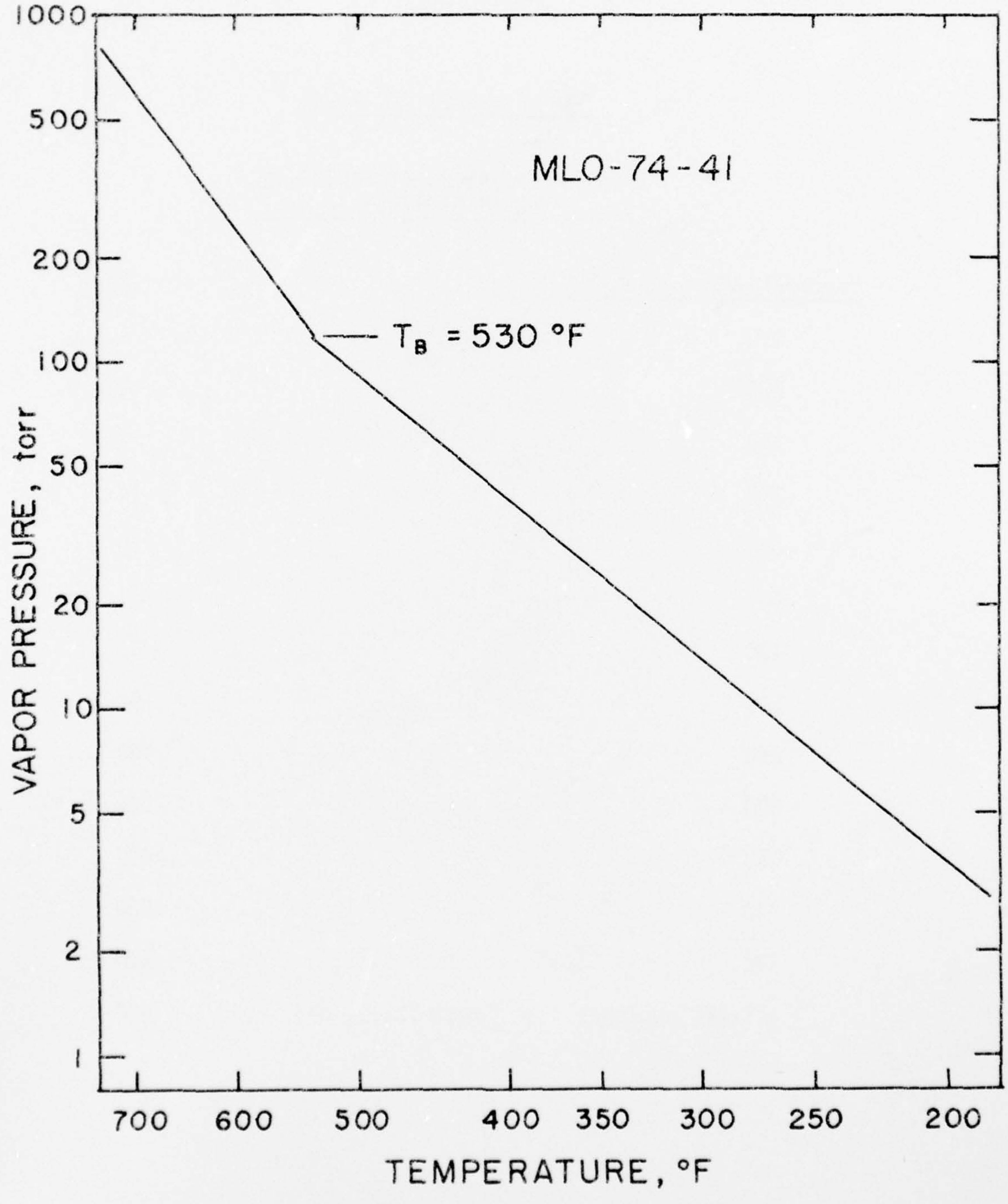

FIGURE 79. MLO-74-41. VAPOR PRESSURE

TABLE CVIII

SAMPLE NUMBER MLO-74-42

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
200	0.1_2
250	0.4
300	1.2
350	3.1
400	7
450	14
500	26
550	60
600	150
650	400
675	580
700	900
Initial Decomposition Temperature, deg. F.	535

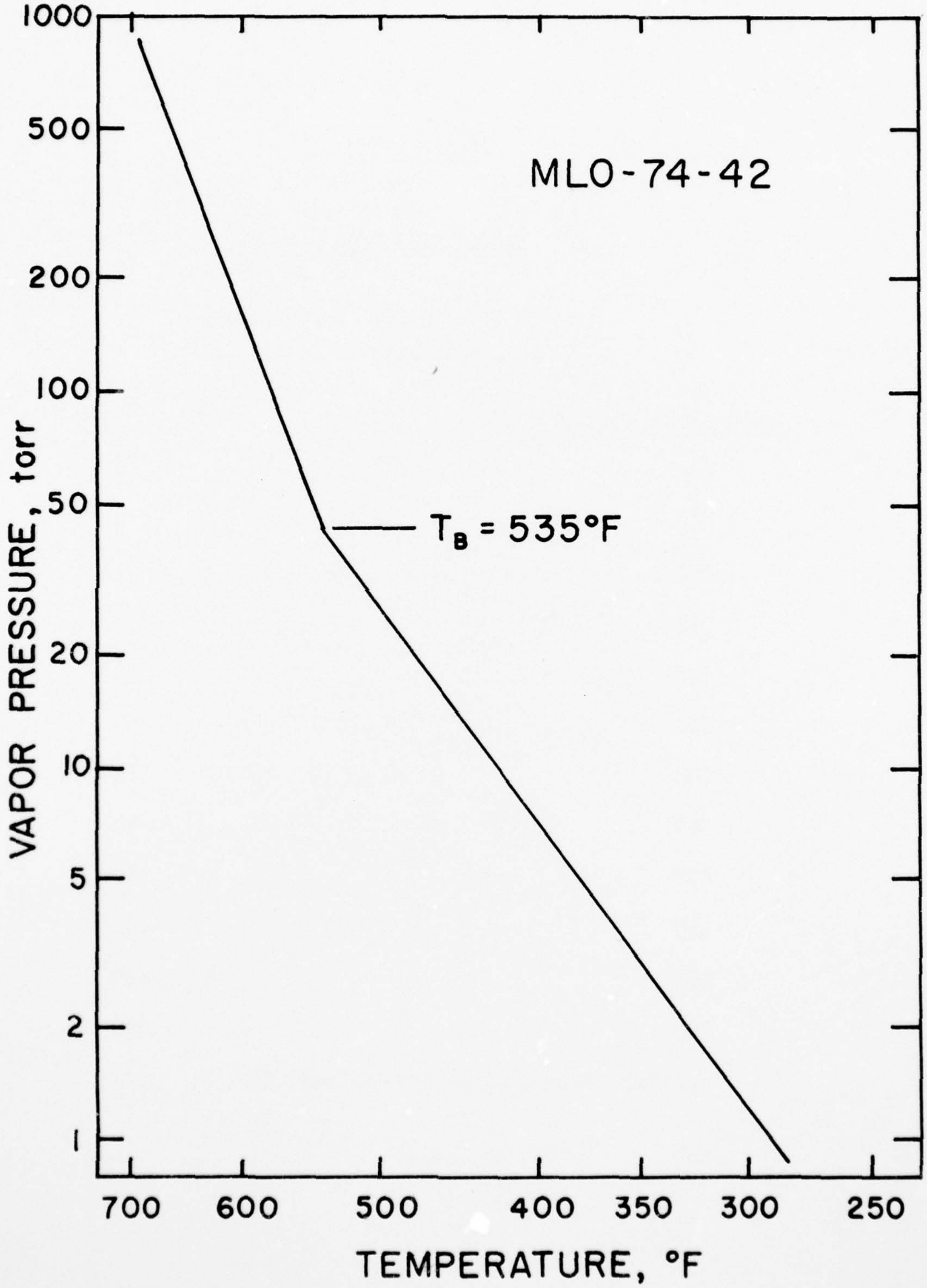

FIGURE 80. MLO-74-42. VAPOR PRESSURE

TABLE CIX

SAMPLE NUMBER MLO-74-48

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879

Temperature, deg. F.	Torr
175	0.1_8
200	0.3_3
250	0.9_6
300	2.5
350	5.4
400	11.8
450	21.9
500	38
550	66
600	105
650	220
700	530
725	800

Initial Decomposition Temperature, deg. F. 619

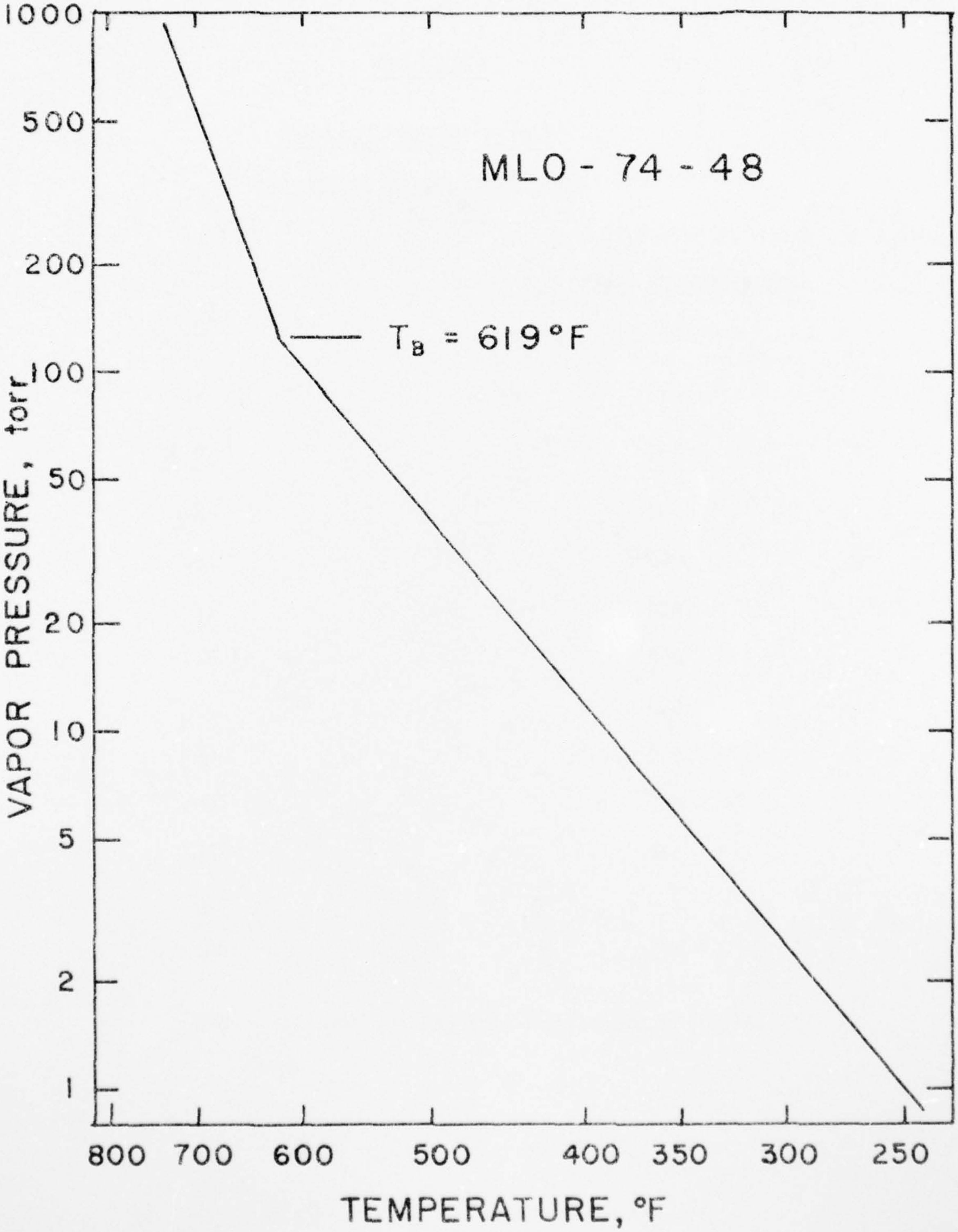

FIGURE 81. MLO-74-48. VAPOR PRESSURE

TABLE CX

SAMPLE NUMBER MLO-74-49

VAPOR PRESSURE BY ISOTENISCOPE (ASTM D 2879)

Temperature, deg. F.	Torr
150	0.2_5
200	0.7
250	1.7
300	3.8
350	7.7
400	14.3
450	24.0
500	38.0
550	61.0
600	89.0
650	129
700	360
725	640

Initial Decomposition Temperature, deg. F. 665

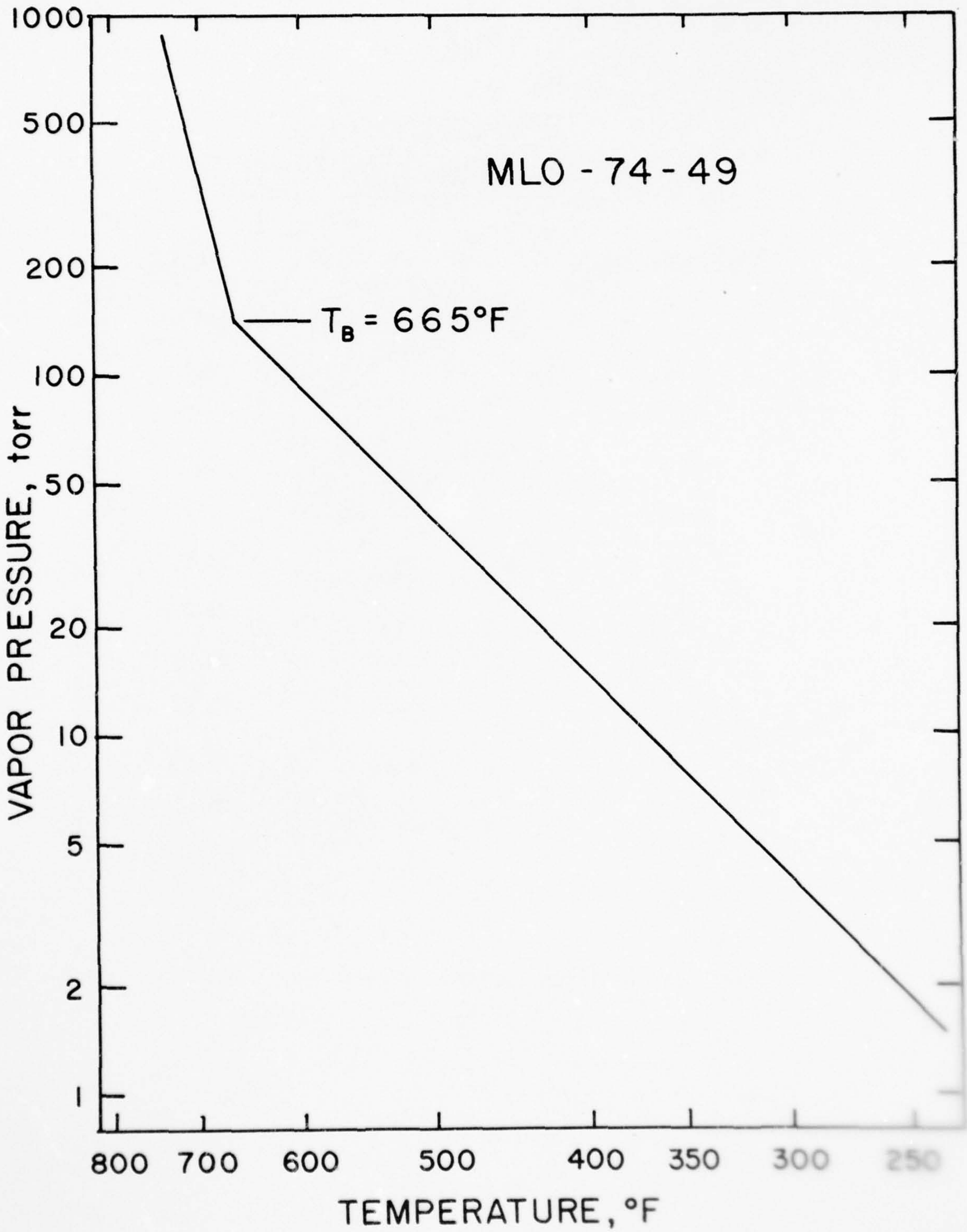

FIGURE 82. MLO-74-49. VAPOR PRESSURE

AD-A037 299 PHOENIX CHEMICAL LAB INC CHICAGO ILL F/G 11/8
CHEMICAL AND PHYSICAL PROPERTIES OF LUBRICANTS AND HYDRAULIC FL--ETC(U)
JUN 76 A A KRAWETZ, G A KRAWETZ, T TOVROG F33615-73-C-5103

UNCLASSIFIED AFML-TR-76-166 NL

4 OF 4
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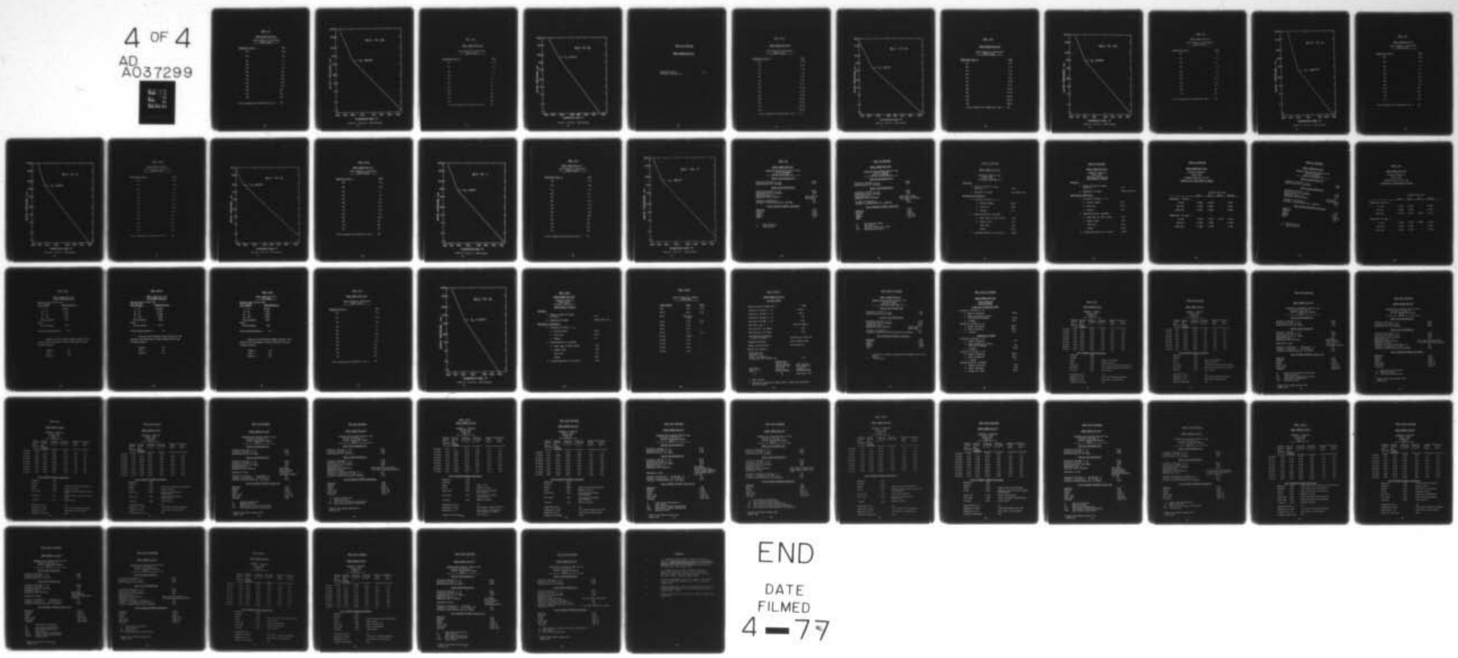

END
DATE
FILMED
4-77

TABLE CXI

SAMPLE NUMBER MLO-74-50

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.1_8
200	0.5_2
250	1.3
300	2.9
350	5.9
400	11.0
450	18.6
500	29.0
550	48.0
600	75.0
650	180
700	390
750	760

Initial Decomposition Temperature, deg. F. 593

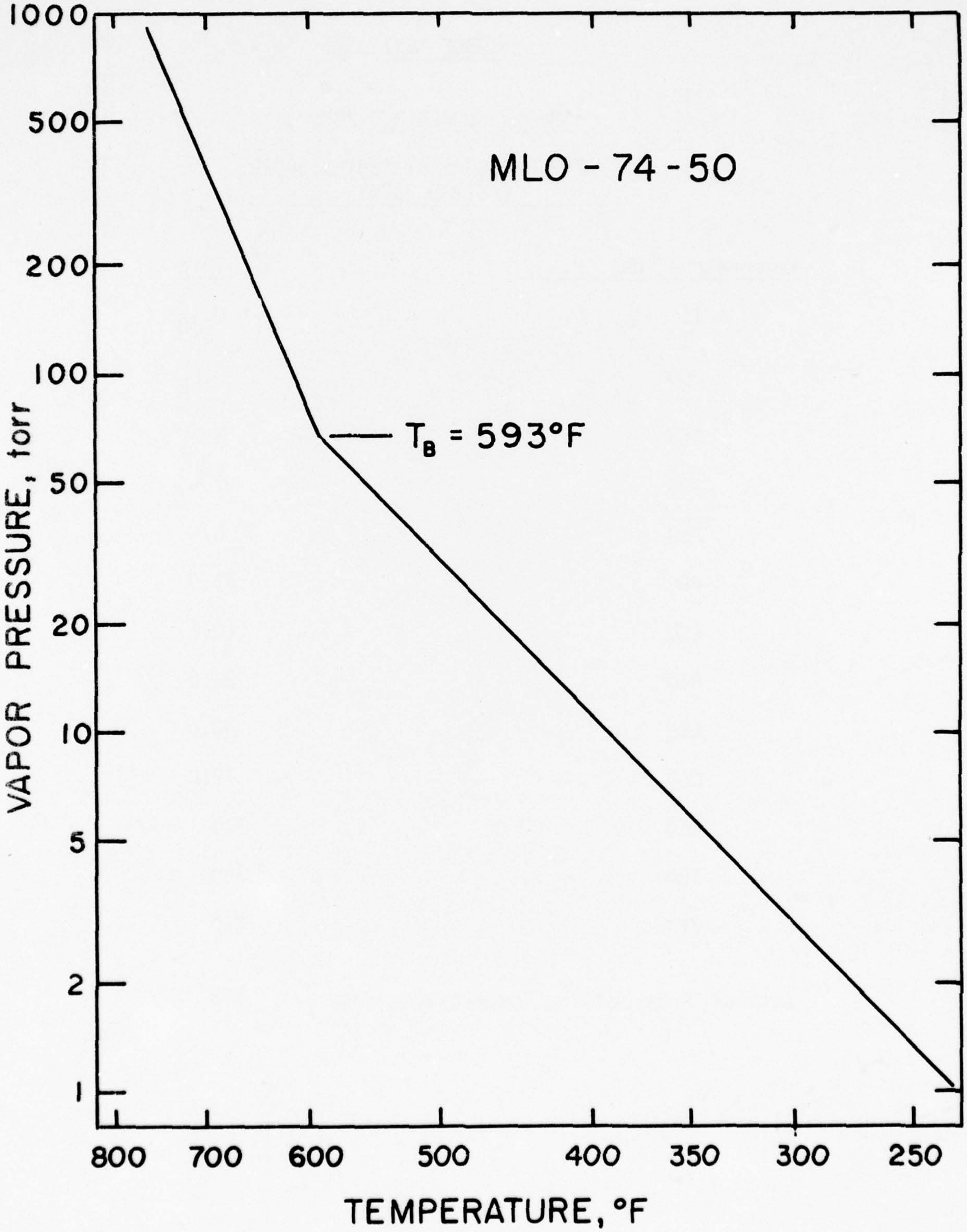

FIGURE 83. MLO-74-50. VAPOR PRESSURE

TABLE CXII

SAMPLE NUMBER MLO-74-53

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.1_3
200	0.5_2
250	1.7
300	5
350	13
400	30
450	60
500	113
550	250
600	520
625	740
Initial Decomposition Temperature, deg. F.	524

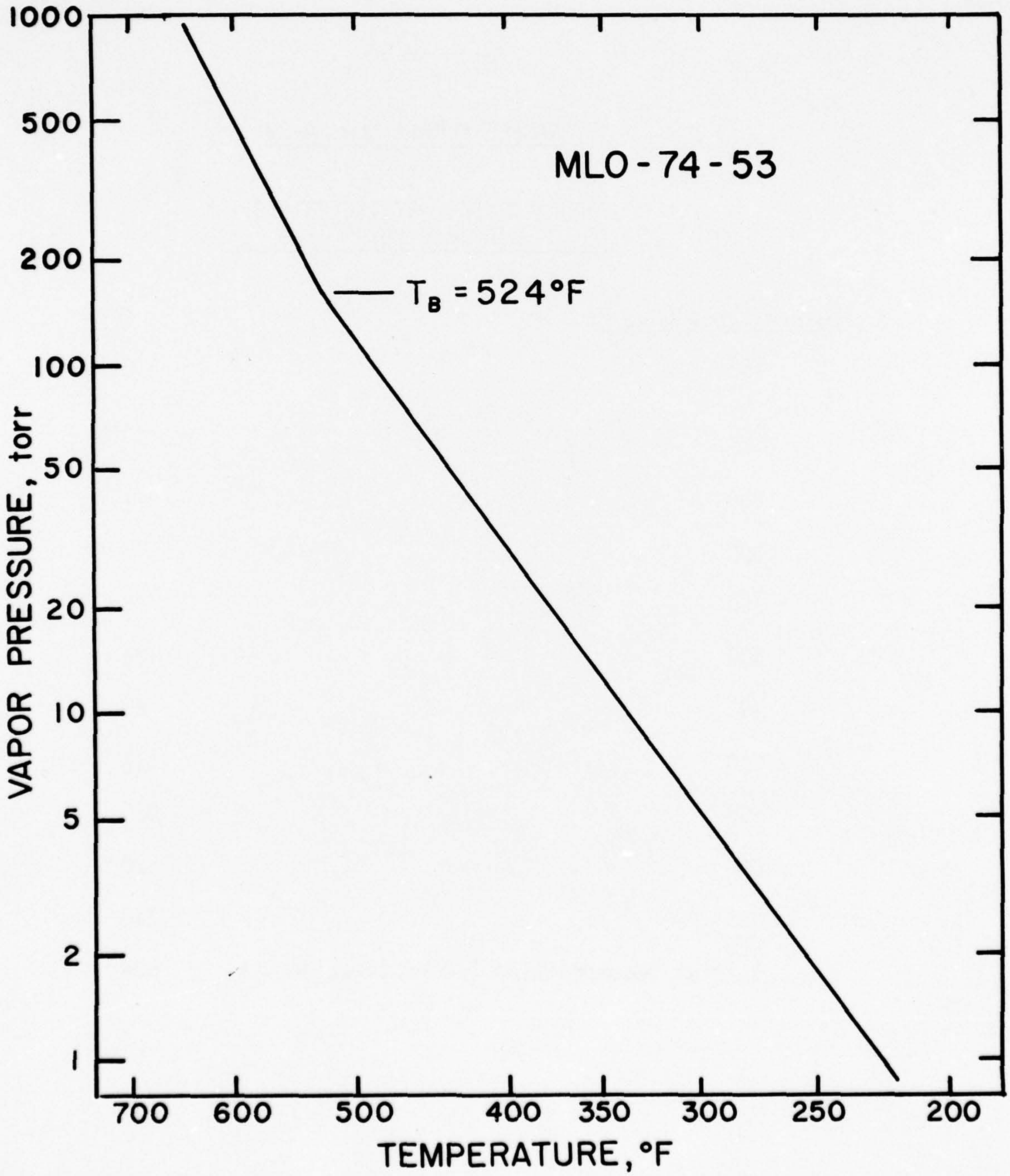

FIGURE 84. MLO-74-53. VAPOR PRESSURE

TABLE CXII CONTINUED

SAMPLE NUMBER MLO-74-53

Evaporation Loss, % (6½ hours @ 300 deg. F.)	11.3

TABLE CXIII

SAMPLE NUMBER MLO-74-54

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
100	0.124
150	0.40
200	1.05
250	2.38
300	4.90
350	9.60
400	16.70
450	26.80
500	41.50
550	64.00
600	132.00
650	279.00
700	520.00
750	930.00
Initial Decomposition Temperature, deg. F.	557

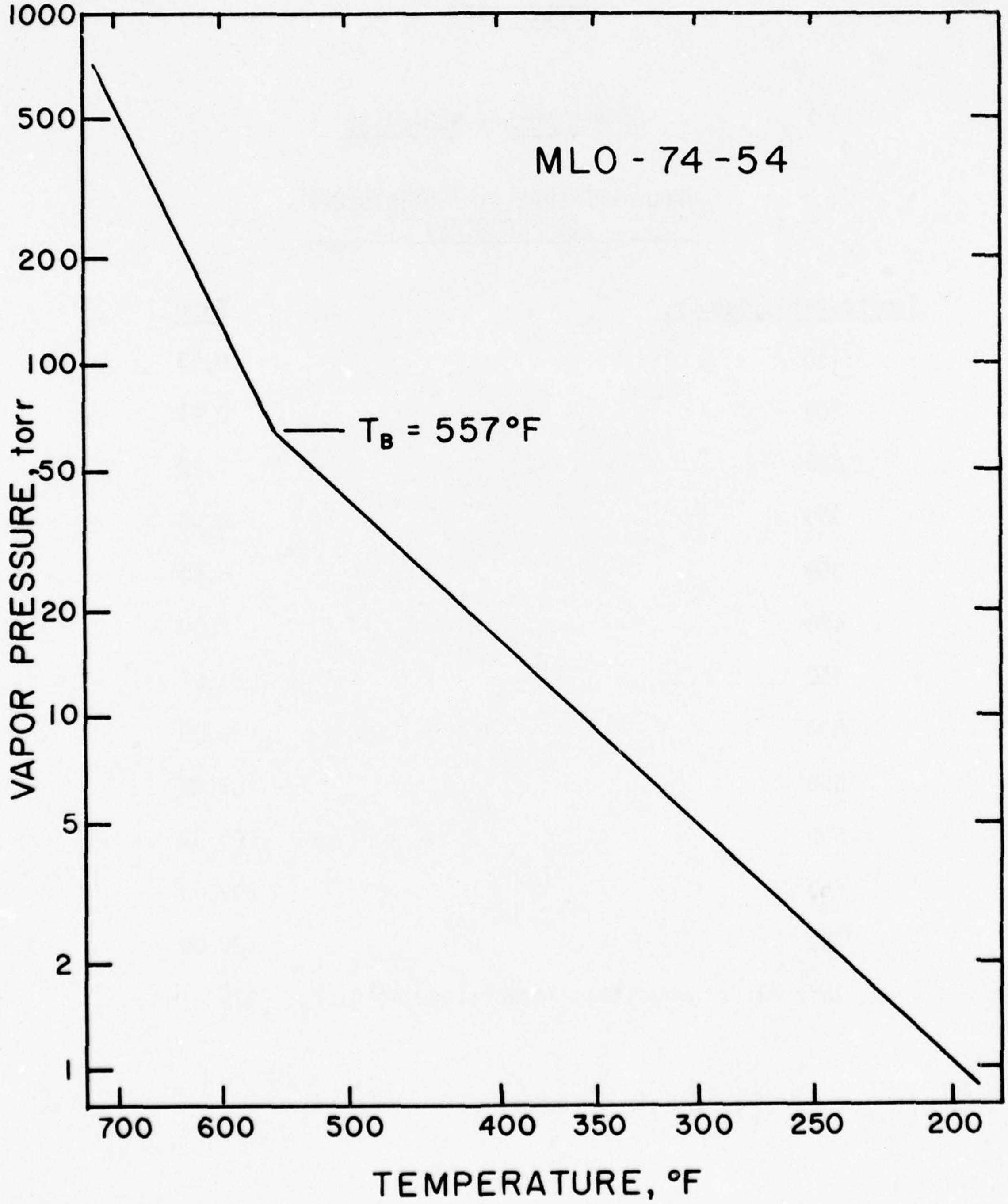

FIGURE 85. MLO-74-54. VAPOR PRESSURE

TABLE CXIV

SAMPLE NUMBER MLO-74-55

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.13
200	0.41
250	1.13
300	2.80
350	6.40
400	12.80
450	23.01
500	39.00
550	67.08
600	100.02
650	259.00
700	580.00
Initial Decomposition Temperature, deg. F.	599

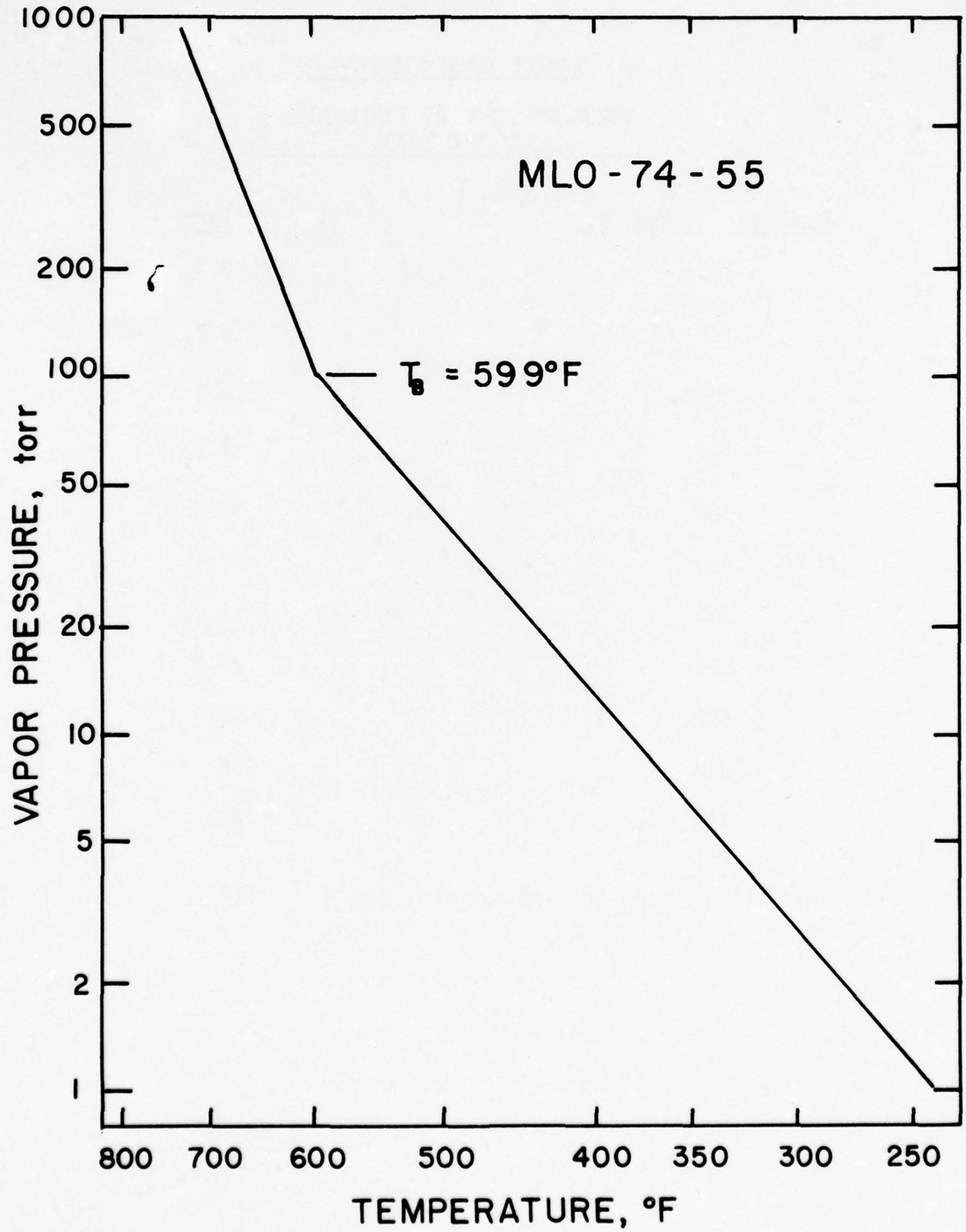

FIGURE 86. MLO-74-55. VAPOR PRESSURE

TABLE CXV

SAMPLE NUMBER MLO-75-8

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
225	0.1_4
250	0.2_5
300	0.7
350	1.7_5
400	3.8
450	7.4
500	14.0
550	25.0
600	51.0
650	220
700	780

Initial Decomposition Temperature, deg. F. 587

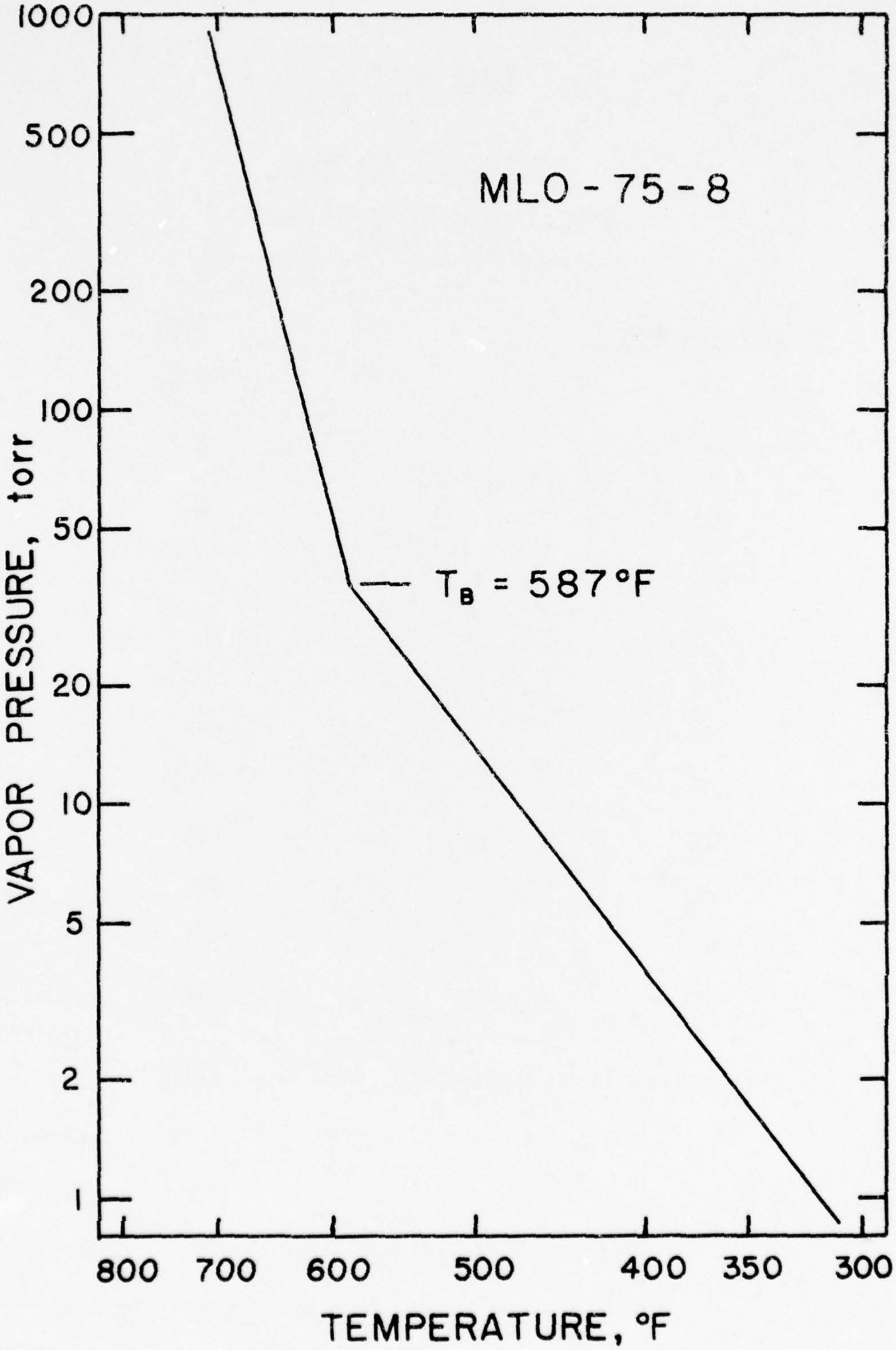

FIGURE 87. MLO-75-8. VAPOR PRESSURE

TABLE CXVI

SAMPLE NUMBER MLO-75-9

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
200	0.2_4
250	0.7_2
300	2.0
350	4.7
400	10.3
450	19.5
500	35.0
550	63.0
600	100
650	205
700	560
725	840

Initial Decomposition Temperature, deg. F. 631

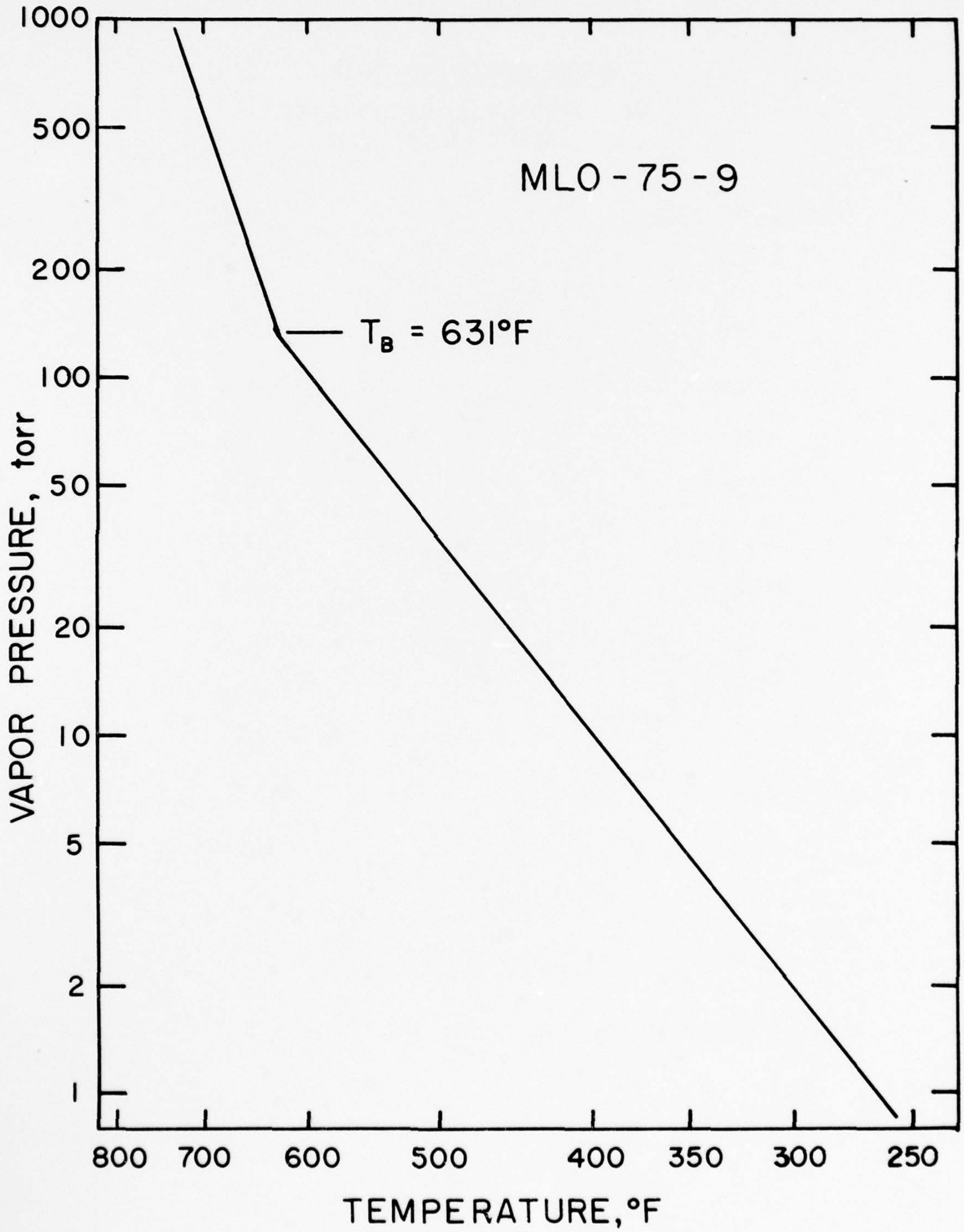

FIGURE 88. MLO-75-9. VAPOR PRESSURE

TABLE CXVII

SAMPLE NUMBER MLO-75-10

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
100	0.2_3
150	0.7_4
200	1.9
250	4.4
300	9.2
350	17.9
400	31.0
450	50.0
500	77.0
550	119
600	169
650	290
700	540
750	920

Initial Decomposition Temperature, deg. F. 625

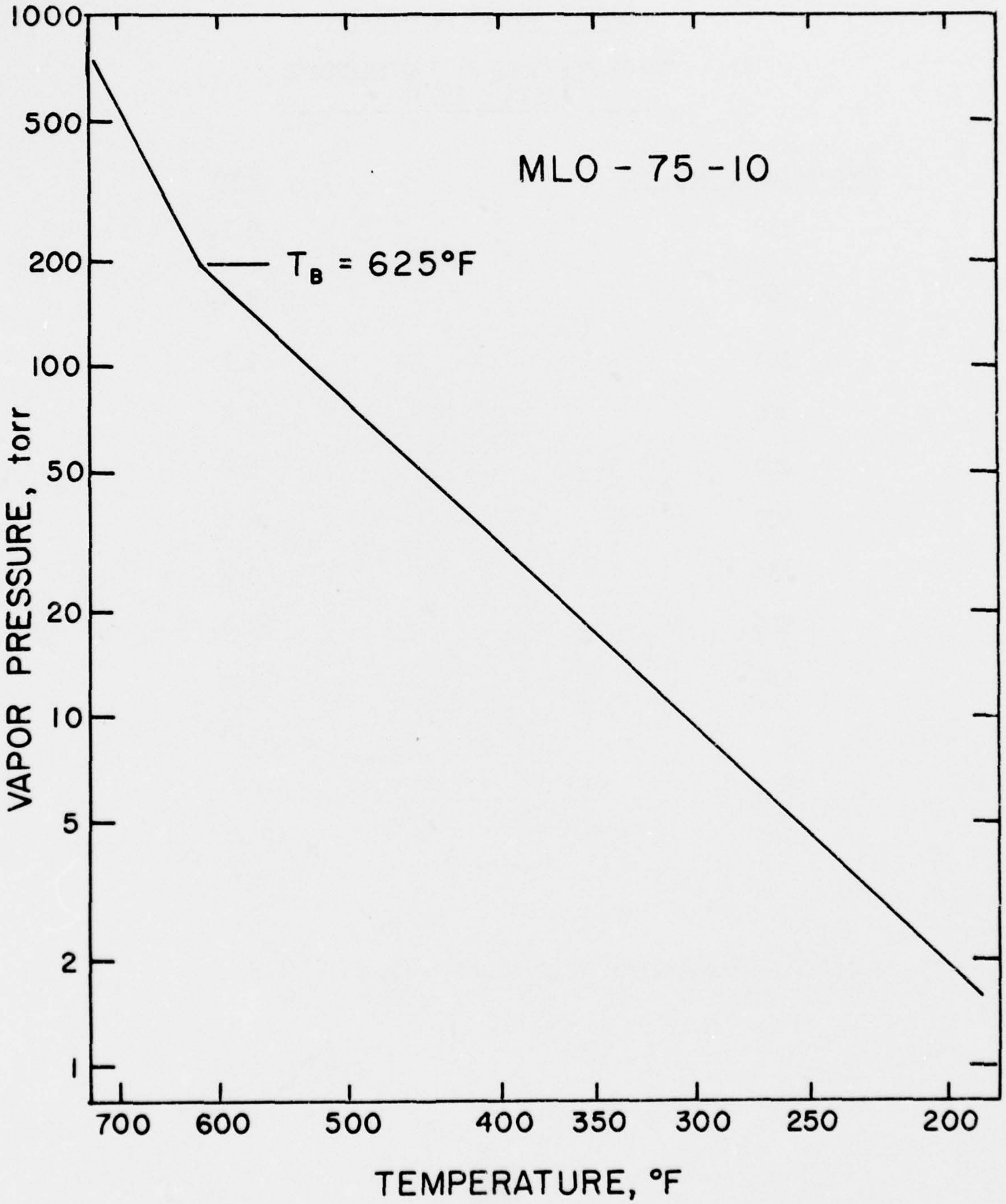

FIGURE 89. MLO-75-10. VAPOR PRESSURE

TABLE CXVIII

SAMPLE NUMBER MLO-75-11

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
150	0.1_4
200	0.4_1
250	1.1
300	2.6
350	5.6
400	10.9
450	19.2
500	32.0
550	54.0
600	80.0
650	180
700	420
750	920

Initial Decomposition Temperature, deg. F. 618

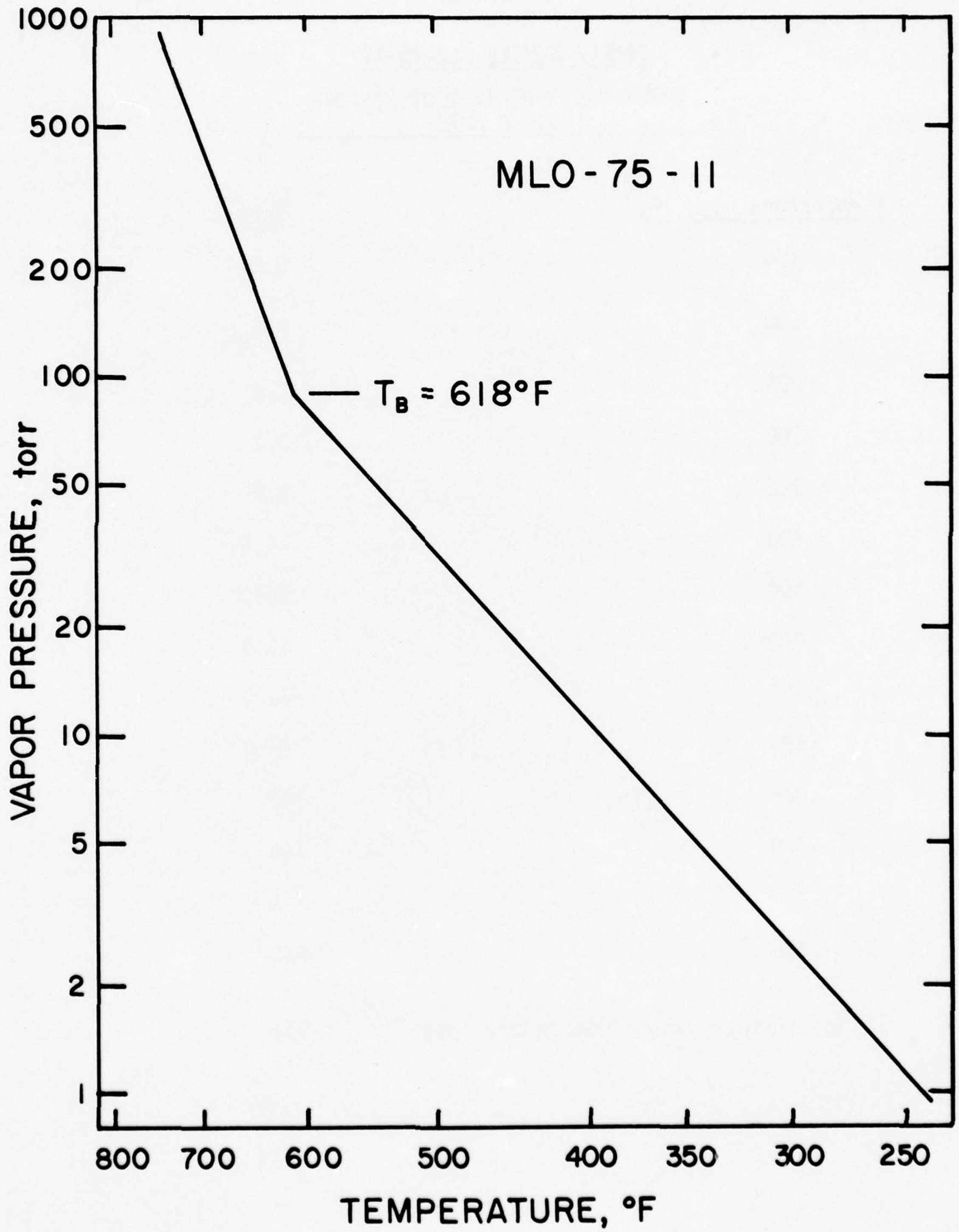

FIGURE 90. MLO-75-11. VAPOR PRESSURE

TABLE CXIX

SAMPLE NUMBER MLO-75-17

VAPOR PRESSURE BY ISOTENISCOPE (ASTM D 2879)

Temperature, deg. F.	Torr
150	0.2$_1$
200	0.6$_2$
250	1.6
300	3.7
350	7.8
400	14.5
450	25.0
500	41.0
550	66.0
600	98.0
650	145
700	340
750	720
775	980

Initial Decomposition Temperature, deg. F. 651

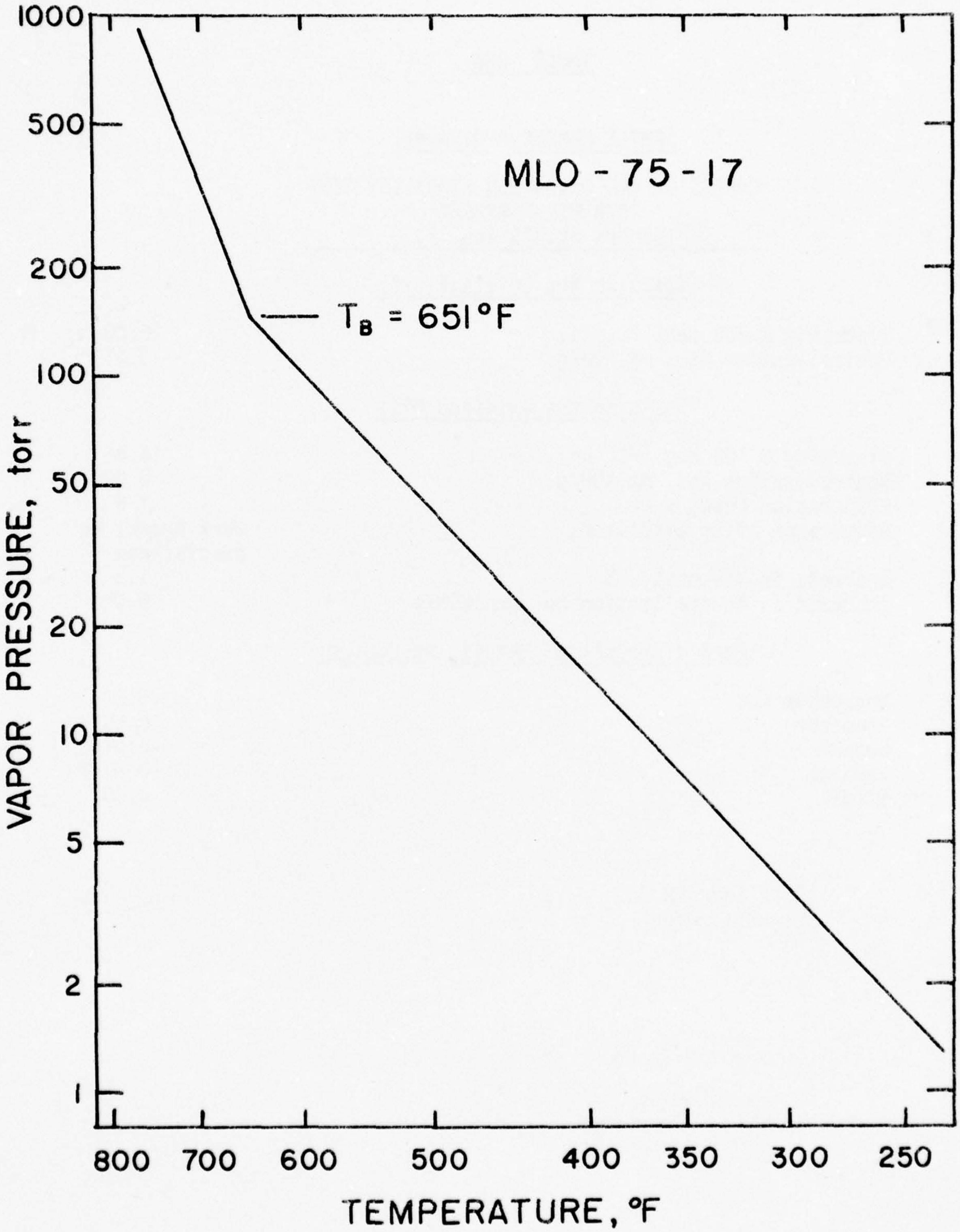

FIGURE 91. MLO-75-17. VAPOR PRESSURE

TABLE CXX

SAMPLE NUMBER MLO-75-40

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs at 275 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.66
Neutralization No., mg.KOH/g.	0.01

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	15.86
Neutralization No., mg.KOH/g.	0.02
Evaporation Loss, %	1.6
Appearance after oxidation:	Dark brown, No precipitate
Increase in Viscosity, %	1.3
Increase in Neutralization No., mg.KOH/g.	0.01

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Copper	-0.01*
Cadmium	-0.01**
Steel	0.00

* Dark tarnish 3a
** Light tarnish

TABLE CXX CONTINUED

SAMPLE NUMBER MLO-75-40

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs. at 325 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	15.66
Neutralization No., mg.KOH/g.	0.01

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	20.76
Neutralization No., mg.KOH/g.	3.56
Evaporation Loss, %	1.0
Appearance after oxidation:	Dark brown, slight light grey precipitate
Increase in Viscosity, %	32.6
Increase in Neutralization No., mg.KOH/g.	3.55

Loss of Weight of Metals, mg./sq.cm:

Magnesium	-7.58 *
Aluminum	0.00
Copper	0.00 **
Cadmium	-5.99 ***
Steel	0.00 ****

*	Dark grey and pitted
**	Dark tarnish
***	Corrosion, pitted and etched
****	Bronze and dark purple

TABLE CXX CONTINUED

SAMPLE NUMBER MLO 75-40

HYDROLYTIC STABILITY TEST
ASTM D 2619
(48 Hours @ 200 deg. F.)

Corrosion:		
1.	Change in weight of copper, mg./sq.cm:	-0.04
2.	Appearance of copper	Dark Tarnish 3A
Resistance to Hydrolysis:		
1.	Viscosity @ 100 deg. F., cs.	
	a. Original sample	15.80
	b. After test	15.69
	c. Change, %	-0.7
2.	Neutralization No., mg.KOH/g.	
	a. Water layer as total acidity	1.60
	b. Organic layer	0.12
	After test	0.13
	Change	-0.01
3.	Insoluble material in oil layer, %	0.001

TABLE CXX CONTINUED

SAMPLE NUMBER MLO-75-40

HYDROLYTIC STABILITY
ASTM D 2619
(48 hours @ 200 deg. F.)
MODIFICATION: 5% WATER

Corrosion:	
1. Change in weight of copper, mg./sq.cm.	0.00
2. Appearance of copper	Slight tarnish 1B
Resistance to Hydrolysis:	
1. Viscosity @ 100 deg. F., cs.	
a. Original sample	15.71
b. After test	15.64
c. Change, %	-0.4
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	0.95
b. Organic layer	0.02
After test	0.10
Change	+0.08
3. Insoluble material in oil layer, %	0.006

TABLE CXX CONTINUED

SAMPLE NUMBER MLO 75-40

NITROGEN SOLUBILITY

ASTM D 2780

STANDARD METHOD OF TEST FOR

SOLUBILITY OF FIXED GASES IN LIQUIDS

	Ostwald Coefficient			
	Run 1	Run 2	Run 3	Average
Temperature: 100 deg. F.				
0 psig	0.0789	0.0793	-	0.0791
500 psig	0.0744	0.0880	-	0.0812
1,000 psig	0.0710	0.0678	-	0.0694
Temperature: 275 deg. F.				
0 psig	0.1077	0.1298	0.1207	0.1194
500 psig	0.1350	0.1385	-	0.1368
1,000 psig	0.1387	0.1344	-	0.1366

TABLE CXX CONTINUED

SAMPLE NUMBER MLO-75-40

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-83282A
168 hrs. at 300 deg. F.

Tests on the Original Oil:	
Viscosity @ 100 deg. F., cs.	15.66
Neutralization No., mg.KOH/g.	0.01
Tests on the Oxidized Oil:	
Viscosity @ 100 deg. F., cs.	15.98
Neutralization No., mg.KOH/g.	0.14
Evaporation Loss, %	1.4
Appearance after oxidation:	Dark brown, No precipitate
Increase in Viscosity, %	2.0
Increase in Neutralization No., mg.KOH/g.	0.13
Loss of Weight of Metals, mg./sq.cm:	
Magnesium	0.00
Aluminum	0.00
Copper	+0.04 *
Cadmium	-0.01 **
Steel	0.00

* Dark tarnish 3a
** Moderate tarnish

TABLE CXXI

SAMPLE NUMBER MLO 75-58

NITROGEN SOLUBILITY

ASTM D 2780

STANDARD METHOD OF TEST FOR

SOLUBILITY OF FIXED GASES IN LIQUIDS

	Ostwald Coefficient			
	Run 1	Run 2	Run 3	Average
Temperature: 100 deg. F.				
0 psig	0.1006	0.1041	-	0.1024
500 psig	0.1038	0.1007	-	0.1022
1,000 psig	0.1130	0.1091	0.1081	0.1101
Temperature: 275 deg. F.				
0 psig	0.1474	0.1485	0.1326	0.1428
500 psig	0.1621	0.1662	-	0.1642
1,000 psig	0.1571	0.1567	-	0.1569

TABLE CXXII

SAMPLE NUMBER MLO 75-75
FRH No Problems Observed

PARTICLE COUNT: PER NAS 1638

SIZE, MICRONS	PARTICLES/100 ml.
5 - 15	133,424
16 - 25	7,593
26 - 50	2,712
51 - 100	431
100 and greater	133
Fibers	
100 and greater	133

Particle Weight.mg/100 ml. 0.8

Amounts of the following elements present in the particles were determined by Atomic Absorption with the following results:

Copper, %	0.3
Iron, %	0.6
Barium, %	9.8

TABLE CXXIII

SAMPLE NUMBER MLO 75-68
FRH Problems Observed

PARTICLE COUNT: PER NAS 1638

SIZE, MICRONS	PARTICLES/100 ml.
5 - 15	1,140,959
16 - 25	67,476
26 - 50	18,403
51 - 100	9,357
100 and greater	3,544
Fibers	
100 and greater	3,119

Particle Weight,mg/100 ml. 1.5

Amounts of the following elements present in the particles were determined by Atomic Absorption with the following results:

Copper, %	0.4
Iron, %	1.2
Barium, %	5.6

TABLE CXXIV

SAMPLE NUMBER MLO 75-70
MIL-H-6083

PARTICLE COUNT: PER NAS 1638

SIZE, MICRONS	PARTICLES/100 ml.
5 - 15	40,568
16 - 25	7,461
26 - 50	2,098
51 - 100	3,713
100 and greater	1,047
Fibers	
100 and greater	286
Particle Weight,mg/100 ml.	0.8

Amounts of the following elements present in the particles were determined by Atomic Absorption with the following results:

Copper, %	0.2
Iron, %	0.8
Barium, %	18.4

TABLE CXXV

SAMPLE NUMBER MLO-75-81

VAPOR PRESSURE BY ISOTENISCOPE
(ASTM D 2879)

Temperature, deg. F.	Torr
225	0.1_2
250	0.2_2
300	0.7_4
350	2.2
400	5.4
450	12.0
500	24.5
550	50.0
600	100
650	250
700	560
725	790

Initial Decomposition Temperature, deg. F. 575

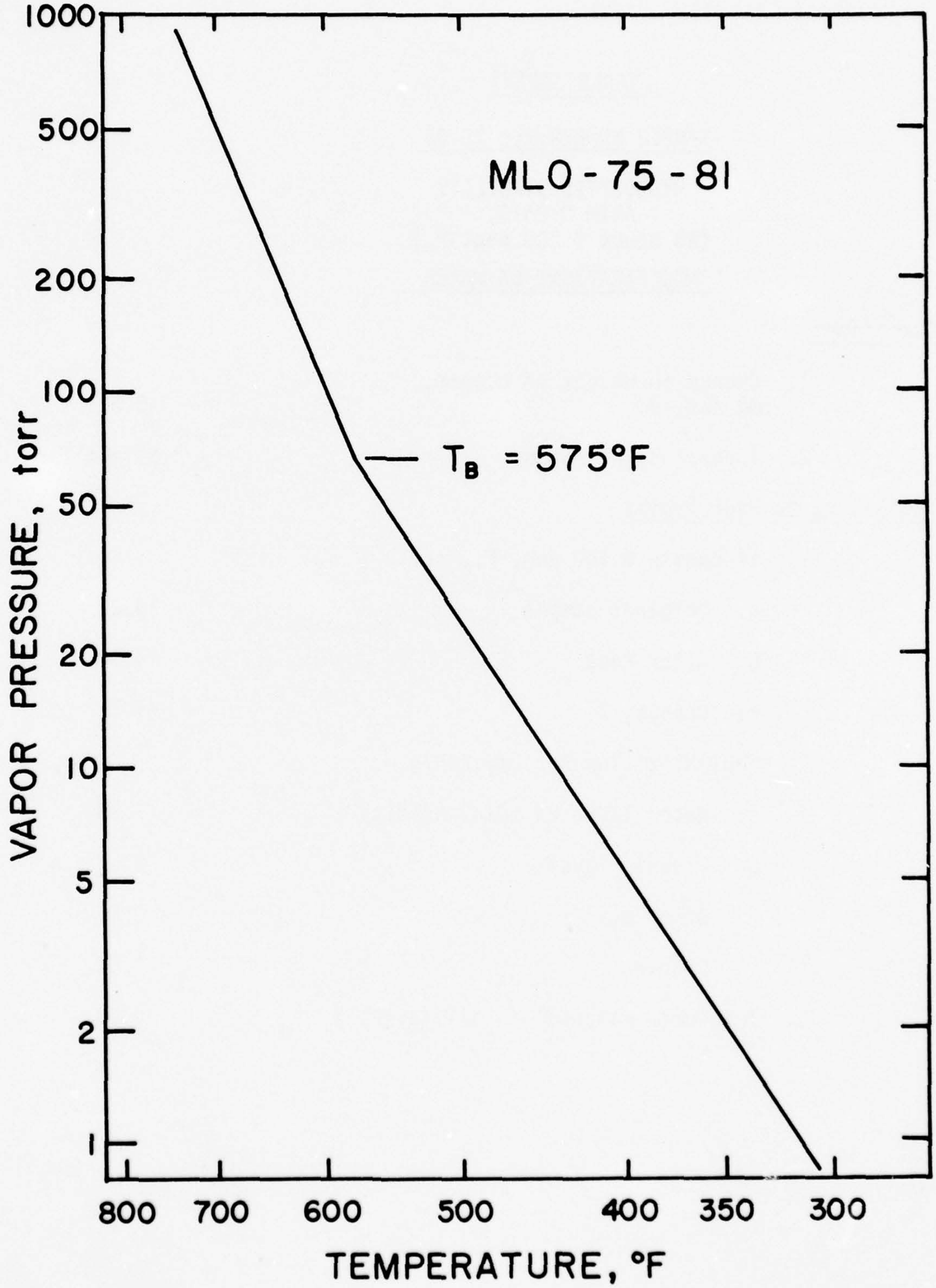

FIGURE 92. MLO-75-81. VAPOR PRESSURE

TABLE CXXVI

SAMPLE NUMBER MLO 75-95

HYDROLYTIC STABILITY
ASTM D 2619
(48 hours @ 200 deg. F.)

MODIFICATION: 5% WATER

Corrosion:

1. Change in weight of copper, mg./sq.cm:	0.0
2. Appearance of copper	Slight Tarnish 1B

Resistance to Hydrolysis:

1. Viscosity @ 100 deg. F., cs.	
a. Original sample	14.28
b. After test	14.44
c. Change, %	+1.1
2. Neutralization No., mg.KOH/g.	
a. Water layer as total acidity	3.35
b. Organic layer	0.04
After test	0.01
Change	-0.03
3. Insoluble material in oil layer, %	0.00

TABLE CXXVII

Sample Number	Neutralization No., mgKOH/g. ASTM D 664	
	Run 1	Run 2
85-6	0.38	0.38
85-71	0.84	0.84
85-72	Less than 0.002	-
85-81	0.95	0.95
85-82	0.02	-
85-91	0.03	-
85-92	1.11	1.11
85-101	0.002	-
85-102	0.04	-
85-111	0.04	-
85-121	0.01	-
85-122	0.08	-

TABLE CXXVIII

SAMPLE NUMBER MLO-76-29

Per MIL-H-5606C

Specific Gravity @ 60/60 deg. F.	1.8552
Viscosity @ -65 deg. F., cs.	1,252.6
Viscosity @ -40 deg. F., cs.	320.4
Viscosity @ 100 deg. F., cs.	7.91
Viscosity @ 210 deg. F., cs.	2.46
Pour Point, deg. F.	Below 85 below 0
Total Acid No., mg. KOH/g.	0.03
Total Base No., mg. KOH/g.	0.00
Low Temperature Stability, 72 hrs. @ -65 deg. F.	Turbidity less than std.
*Evaporation Residue	Hard, slightly tacky
*Copper Strip Corrosion	Dark tarnish 3b
**Water, Karl Fischer, %	
4-Ball Wear Test 1200 RPM, 1 hr., 10 KG., @ 167 deg. F. Average Wear Spot Diameter, mm.	0.81

Foaming Test:

Temperature, Deg. F.	Foaming Tendency: Foam volume, ml. at end of blowing period	Foam Stability Foam volume, ml. at end of settling period
75	20	zero after 0'19"

* Shows failure

** Can not run, because the sample forms a rubber-like precipitate with the solvent.

TABLE CXXVIII CONTINUED

SAMPLE NUMBER MLO-76-29

CORROSION AND OXIDATION STABILITY TEST
PER MIL-H-5606C
168 Hours at 275 deg. F.

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	7.91
Neutralization No., mg.KOH/g.	0.03

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	10.72
Neutralization No., mg.KOH/g.	0.03
Evaporation Loss, %	20.8
Appearance after oxidation:	Light straw, no precipitate
Increase in Viscosity, %	35.5
Increase or Decrease in Neutralization No.,mg.KOH/g.	0.0

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Copper	+0.03*
Cadmium	0.00**
Steel	0.00

* Corrosion 4a, etched; transparent brown deposit over entire surface

** Light tarnish

TABLE CXXVIII CONTINUED

SAMPLE NUMBER MLO-76-29

SONIC SHEAR TEST
Per MIL-H-5606C

Properties of Reference Fluid

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	14.41
b. After irradiation of 30 ml. of fluid for 30 minutes.	12.23
c. % change	-15.13
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	488.8
b. After irradiation	422.5
c. % change	-13.6

Properties of Sample

Viscosity @ 100 deg. F., cs:	
a. Before irradiation	7.91
b. After irradiation of 30 ml. fluid for 30 minutes	7.94
c. % change	+0.38
Viscosity @ -40 deg. F., cs:	
a. Before irradiation	320.4
b. After irradiation	315.9
c. % change	-1.4
Neutralization No., mg.KOH/g.	
a. Before irradiation	0.05
b. After irradiation	0.09
c. Change, mg. KOH/g.	+0.04

TABLE CXXIX

SAMPLE NUMBER ATL-3173

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.22	-----	12.85	3.09	-----	-----
16 hours	0.21	-0.01	13.19	3.27	+2.6	+5.8
24 hours	0.23	+0.01	13.19	3.18	+2.6	+2.9
40 hours	0.28	+0.06	13.50	3.22	+5.0	+4.2
48 hours	0.35	+0.13	13.60	3.26	+5.8	+5.5
64 hours	0.42	+0.20	13.77	3.29	+7.2	+6.5
72 hours	0.48	+0.26	13.65	3.25	+6.2	+5.2
88 hours	0.48	+0.26	13.83	3.17	+7.6	+2.6
96 hours	0.52	+0.30	13.70	3.29	+6.6	+6.5

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Brassy discoloration
Silver	-0.04	Moderate tarnish
Steel M-50	0.00	Dark bronze and purple discoloration
Mild Steel	0.00	Dark bronze and purple discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	1.0
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXIX CONTINUED

SAMPLE NUMBER ATL-3173

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.22	-----	12.85	3.09	-----	-----
16 hours	0.21	-0.01	13.21	3.16	+2.8	+2.3
24 hours	0.23	+0.01	13.16	3.17	+2.4	+2.6
40 hours	0.26	+0.04	13.47	3.21	+4.8	+3.9
48 hours	0.28	+0.06	13.56	3.18	+3.2	+2.9
64 hours	0.36	+0.14	13.65	3.18	+6.2	+2.9
72 hours	0.42	+0.20	13.73	3.25	+6.8	+5.2
88 hours	0.46	+0.24	13.80	3.24	+7.4	+4.8
96 hours	0.50	+0.28	13.61	3.29	+5.9	+6.5

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Brassy discoloration
Silver	-0.04	Moderate tarnish
Steel M-50	0.00	Dark bronze and purple discoloration
Mild Steel	0.00	Dark bronze and purple discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	1.3
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown; no precipitate
Sludge by centrifuge	None

TABLE CXXIX CONTINUED

SAMPLE NUMBER ATL-3173 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	12.85
Viscosity @ 210 deg. F., cs.	3.09
Neutralization No., mg. KOH/g.	0.22

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.46
Viscosity @ 210 deg. F., cs.	3.30
Neutralization No., mg. KOH/g.	0.63
Evaporation Loss, %	0.1
Appearance after oxidation:	Dark Brown, No precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity, % (@ 100 deg. F.)	12.5
Increase in Viscosity, % (@ 210 deg. F.)	6.8
Increase in Neutralization No., mg. KOH/g.	0.41

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	- 0.04 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 *****

* Brown & faint purple discoloration
** Moderate tarnish
*** Dark bronze & purple discoloration
**** Multicolor discoloration
***** Moderate tarnish

∇ Federal Test Method Standard 791b
Method 5307.

TABLE CXXIX CONTINUED

SAMPLE NUMBER ATL-3173 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	12.85
Viscosity @ 210 deg. F., cs.	3.09
Neutralization No., mg.KOH/g.	0.22

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	13.68
Viscosity @ 210 deg. F., cs.	3.28
Neutralization No., mg.KOH/g.	0.61
Evaporation Loss, %	0.5
Appearance after oxidation:	Dark brown, no precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity @ 100 deg. F., %	6.4
Increase in Viscosity @ 210 deg. F., %	6.1
Increase in Neutralization No., mg.KOH/g.	0.39

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	-0.05 **
Steel M-50	0.00 ***
Mild Steel	0.00 ***
Titanium	0.00 **

* Copper color discoloration
** Moderate tarnish
*** Dark bronze discoloration

∇ Federal Test Method Standard 791b
Method 5307.

TABLE CXXX

SAMPLE NUMBER ATL-3174

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.09	-----	13.51	3.25	-----	-----
16 hours	0.13	+0.04	13.85	3.31	+2.5	+1.8
24 hours	0.16	+0.07	13.93	3.31	+3.1	+1.8
40 hours	0.25	+0.16	14.18	3.35	+5.0	+3.1
48 hours	0.30	+0.21	14.22	3.35	+5.2	+3.1
64 hours	0.38	+0.29	14.35	3.38	+6.2	+4.0
72 hours	0.39	+0.30	14.37	3.36	+6.4	+3.4
88 hours	0.38	+0.29	14.46	3.36	+7.0	+3.4
96 hours	0.48	+0.39	14.57	3.38	+7.8	+4.0

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Brassy and yellow discoloration
Silver	0.00	Moderate tarnish
Steel M-50	0.00	Bronze and faint purple discoloration
Mild Steel	0.00	Bronze and faint purple discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	3.3
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXX CONTINUED

SAMPLE NUMBER ATL-3174

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.09	-----	13.51	3.25	-----	-----
16 hours	0.10	+0.01	14.02	3.39	+3.8	+4.3
24 hours	0.14	+0.05	13.91	3.28	+3.0	+0.9
40 hours	0.22	+0.13	14.15	3.31	+4.7	+1.8
48 hours	0.21	+0.12	14.13	3.35	+4.6	+3.1
64 hours	0.37	+0.28	14.26	3.31	+5.6	+1.8
72 hours	0.38	+0.29	14.33	3.37	+6.1	+3.7
88 hours	0.41	+0.32	14.72	3.37	+8.9	+3.7
96 hours	0.47	+0.38	14.41	3.41	+6.7	+4.9

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Brassy and yellowish discoloration
Silver	0.00	Moderate tarnish
Steel M-50	0.00	Bronze and faint purple discoloration
Mild Steel	0.00	Bronze and faint purple discoloration
Titanium	0.00	Light tarnish
Evaporation Loss, %		2.2
Appearance of tube		A few small gelatinous globules
Appearance of oil		Dark brown; no precipitate
Sludge by centrifuge		None

TABLE CXXX CONTINUED

SAMPLE NUMBER ATL-3174 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	13.51
Viscosity @ 210 deg. F., cs.	3.25
Neutralization No., mg. KOH/g.	0.09

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.43
Viscosity @ 210 deg. F., cs.	3.41
Neutralization No., mg. KOH/g.	0.62
Evaporation Loss, %	0.6
Appearance after oxidation:	Dark Brown, No precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity, % (@ 100 deg. F.)	6.8
Increase in Viscosity, % (@ 210 deg. F.)	4.9
Increase in Neutralization No., mg. KOH/g.	0.53

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	- 0.02 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00

* Brassy discoloration
** Moderate tarnish
*** Bronze & faint purple discoloration
**** Dark bronze & purple discoloration

∇ Federal Test Method Standard 791b
Method 5307.

TABLE CXXX CONTINUED

SAMPLE NUMBER ATL-3174 ▽

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	13.51
Viscosity @ 210 deg. F., cs.	3.25
Neutralization No., mg.KOH/g.	0.09

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.34
Viscosity @ 210 deg. F., cs.	3.35
Neutralization No., mg.KOH/g.	0.56
Evaporation Loss, %	0.4
Appearance after oxidation:	Dark brown, no precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity @ 100 deg. F., %	6.1
Increase in Viscosity @ 210 deg. F., %	3.1
Increase in Neutralization No., mg.KOH/g.	0.47

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Bronze	-0.02 *
Silver	-0.04 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 **

* Brassy discoloration
** Moderate tarnish
*** Dark bronze and purple discoloration
**** Brassy and yellowish discoloration

▽ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXI

SAMPLE NUMBER ATL-3175

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.12	-----	13.72	3.36	-----	-----
16 hours	0.14	+0.02	13.79	3.42	+0.5	+1.8
24 hours	0.20	+0.08	14.05	3.45	+2.4	+2.6
40 hours	0.25	+0.13	14.19	3.51	+3.4	+4.5
48 hours	0.34	+0.22	14.23	3.47	+3.7	+3.3
64 hours	0.43	+0.31	14.41	3.40	+5.0	+1.2
72 hours	0.47	+0.35	14.47	3.48	+5.5	+3.6
88 hours	0.47	+0.35	14.58	3.51	+6.3	+4.5
96 hours	0.58	+0.46	14.47	3.52	+5.5	+4.8

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Copper color
Silver	-0.06	Moderate tarnish
Steel M-50	0.00	Dark bronze and purple discoloration
Mild Steel	0.00	Dark bronze and purple discoloration
Titanium	0.00	Moderate tarnish

Evaporation Loss, %	3.9
Appearance of tube	Brown powdery deposit and film
Appearance of oil	Dark brown, no precipitate, slight amount of sludge
Sludge by centrifuge, %	Less than 0.2

TABLE CXXXI CONTINUED

SAMPLE NUMBER ATL-3175

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.12	-----	13.72	3.36	-----	-----
16 hours	0.16	+0.04	13.96	3.45	+1.7	+2.7
24 hours	0.19	+0.07	14.04	3.45	+2.3	+2.7
40 hours	0.25	+0.13	13.67	3.47	-0.4	+3.3
48 hours	0.29	+0.17	13.66	3.49	-0.4	+3.9
64 hours	0.37	+0.25	14.30	3.36	+4.2	0.0
72 hours	0.42	+0.30	14.38	3.51	+4.8	+4.5
88 hours	0.48	+0.36	14.48	3.53	+5.5	+5.1
96 hours	0.52	+0.40	14.24	3.51	+3.8	+4.5

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Copper colored discoloration
Silver	-0.09	Moderate tarnish
Steel M-50	0.00	Dark bronze and purple discoloration
Mild Steel	0.00	Dark bronze and purple discoloration
Titanium	0.00	Moderate tarnish

Evaporation Loss, %	3.3
Appearance of tube	Slight brown deposit and film
Appearance of oil	Dark brown; no precipitate
Sludge by centrifuge	Trace

TABLE CXXXI CONTINUED

SAMPLE NUMBER ATL-3175 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	13.72
Viscosity @ 210 deg. F., cs.	3.36
Neutralization No., mg. KOH/g.	0.12

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.53
Viscosity @ 210 deg. F., cs.	3.51
Neutralization No., mg. KOH/g.	0.63
Evaporation Loss, %	0.9
Appearance after oxidation:	Dark Brown, No precipitate and Slight sludge formation
Appearance of tube	Brown powdery deposit and film
Increase in Viscosity, % (@ 100 deg. F.)	5.9
Increase in Viscosity, % (@ 210 deg. F.)	4.5
Increase in Neutralization No., mg. KOH/g.	0.51

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	- 0.11 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 *****

* Faint purple discoloration
** Light tarnish
*** Dark bronze & purple discoloration
**** Dark bronze & purple discoloration
***** Moderate tarnish

∇ Federal Test Method Standard 791b Method 5307.

TABLE CXXXI CONTINUED

SAMPLE NUMBER ATL-3175 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	13.72
Viscosity @ 210 deg. F., cs.	3.36
Neutralization No., mg.KOH/g.	0.12

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.38
Viscosity @ 210 deg. F., cs.	3.51
Neutralization No., mg.KOH/g.	0.64
Evaporation Loss, %	1.3
Appearance after oxidation:	Dark brown, no precipitate
Appearance of tube	Brown powdery deposit and film
Increase in Viscosity @ 100 deg. F., %	4.8
Increase in Viscosity @ 210 deg. F., %	4.5
Increase in Neutralization No., mg.KOH/g.	0.52

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	-0.13 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 *****

*	Faint purple discoloration
**	Light yellowish discoloration
***	Dark bronze and purple discoloration
****	Dark bronze and light purple discoloration
*****	Faint purple and light yellowish discoloration

∇ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXII

SAMPLE NUMBER ATL-3176

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.15	-----	27.52	5.04	-----	-----
16 hrs.	0.10	-0.05	28.57	5.14	+3.8	+2.0
24 hrs.	0.14	-0.01	28.82	5.31	+4.7	+5.4
40 hrs.	0.12	-0.03	29.27	5.28	+6.4	+4.8
48 hrs.	0.13	-0.02	29.49	5.33	+7.2	+5.8
64 hrs.	0.14	-0.01	29.77	5.39	+8.2	+6.9
72 hrs.	0.16	+0.01	30.13	5.44	+9.5	+7.9
88 hrs.	0.15	0.00	30.28	5.44	+10.0	+7.9
96 hrs.	0.20	+0.05	30.25	5.40	+9.9	+7.1

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	-0.06	Copper colored discoloration
Silver	-0.02	Moderate tarnish and faint purple discoloration
Steel M-50	0.00	Brassy discoloration
Mild Steel	0.00	Brassy and faint purple discoloration
Titanium	0.00	Moderate tarnish

Evaporation Loss, %	4.2
Appearance of tube	Light brown film and deposit
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXXII CONTINUED

SAMPLE NUMBER ATL-3176

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.15	-----	27.52	5.04	-----	-----
16 hours	0.07	-0.08	28.45	5.13	+3.4	+1.8
24 hours	0.07	-0.08	28.72	5.22	+4.4	+3.6
40 hours	0.06	-0.09	29.21	5.26	+6.1	+4.4
48 hours	0.09	-0.06	29.42	5.25	+6.9	+4.2
64 hours	0.13	-0.02	29.82	5.31	+8.4	+5.4
72 hours	0.12	-0.03	29.72	5.33	+8.0	+5.8
88 hours	0.14	-0.01	30.11	5.38	+9.4	+6.7
96 hours	0.14	-0.01	30.32	5.42	+10.2	+7.5

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	0.00	Copper colored discoloration
Silver	-0.04	Moderate tarnish and faint purple discoloration
Steel M-50	0.00	Brassy discoloration
Mild Steel	0.00	Brassy and purple discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	3.3
Appearance of tube	Light brown deposit and film
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXXII CONTINUED

SAMPLE NUMBER ATL-3176 ▽

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	27.52
Viscosity @ 210 deg. F., cs.	5.04
Neutralization No., mg. KOH/g.	0.15

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	30.48
Viscosity @ 210 deg. F., cs.	5.36
Neutralization No., mg. KOH/g.	0.23
Evaporation Loss, %	0.9
Appearance after oxidation:	Dark Brown, No precipitate
Appearance of tube	Slight amount of gelatinous particles and film
Increase in Viscosity, % (@ 100 deg. F.)	10.7
Increase in Viscosity, % (@ 210 deg. F.)	6.3
Increase in Neutralization No., mg. KOH/g.	0.08

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	0.02 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 *****

*	Brown discoloration
**	Moderate tarnish
***	Dark bronze discoloration
****	Dark bronze & purple discoloration
*****	Light tarnish discoloration

▽ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXII CONTINUED

SAMPLE NUMBER ATL-3176 ▽

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	27.52
Viscosity @ 210 deg. F., cs.	5.04
Neutralization No., mg.KOH/g.	0.15

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	30.41
Viscosity @ 210 deg. F., cs.	5.36
Neutralization No., mg.KOH/g.	0.21
Evaporation Loss, %	0.7
Appearance after oxidation:	Dark brown, no precipitate
Appearance of tube	A small amount of gelatinous particles and film
Increase in Viscosity @ 100 deg. F., %	10.5
Increase in Viscosity @ 210 deg. F., %	6.3
Increase in Neutralization No., mg.KOH/g.	0.06

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Bronze	0.00 *
Silver	0.00 **
Steel M-50	0.00 ***
Mild Steel	0.00 ***
Titanium	0.00 ****

* Copper color discoloration
** Moderate tarnish
*** Dark bronze and purple discoloration
**** Light tarnish

▽ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXIII

SAMPLE NUMBER ATL-3177

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.22	-----	12.88	3.44	-----	-----
16 hrs.	0.42	0.20	12.96	3.45	+0.6	+0.3
24 hrs.	0.42	0.20	13.01	3.46	+1.0	+0.6
40 hrs.	0.58	0.36	12.86	3.40	0.0	-1.2
48 hrs.	0.53	0.41	12.91	3.46	+0.2	+0.6
64 hrs.	0.73	0.51	12.87	3.46	0.0	+0.6
72 hrs.	0.78	0.56	12.87	3.46	0.0	+0.6
88 hrs.	0.87	0.65	12.84	3.45	0.0	+0.3
96 hrs.	0.96	0.74	12.90	3.45	0.0	+0.3

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	Light tarnish and multicolor discoloration
Aluminum	0.00	Light multicolor discoloration
Bronze	-0.07	Brassy and yellow discoloration
Silver	-0.02	Moderate tarnish
Steel M-50	0.00	Brassy and purple discoloration
Mild Steel	0.00	Brassy and purple discoloration
Titanium	0.00	Moderate tarnish

Evaporation Loss, %	2.4
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXXIII CONTINUED

SAMPLE NUMBER ATL-3177

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.22	-----	12.88	3.44	-----	-----
16 hours	0.35	+0.13	12.93	3.43	+0.4	-0.3
24 hours	0.38	+0.16	12.96	3.43	+0.6	-0.3
40 hours	0.49	+0.27	13.00	3.46	+0.9	+0.6
48 hours	0.64	+0.42	13.00	3.50	+0.9	+1.7
64 hours	0.69	+0.47	13.02	3.46	+1.1	+0.6
72 hours	0.74	+0.52	13.02	3.46	+1.1	+0.6
88 hours	0.86	+0.64	13.07	3.46	+1.5	+0.6
96 hours	0.94	+0.72	12.96	3.44	+0.6	0.0

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	Multicolor discoloration
Aluminum	0.00	Light tarnish
Bronze	-0.02	Multicolor discoloration
Silver	-0.02	Moderate tarnish
Steel M-50	0.00	Multicolor discoloration
Mild Steel	0.00	Multicolor discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	2.6
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXXIII CONTINUED

SAMPLE NUMBER ATL-3177 ▽

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	12.88
Viscosity @ 210 deg. F., cs.	3.44
Neutralization No., mg. KOH/g.	0.22

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	13.04
Viscosity @ 210 deg. F., cs.	3.44
Neutralization No., mg. KOH/g.	1.12
Evaporation Loss, %	0.8
Appearance after oxidation:	Dark Brown, No precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity, % (@ 100 deg. F.)	1.2
Change in Viscosity, % (@ 210 deg. F.)	0.0
Increase in Neutralization No., mg. KOH/g.	0.90

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00 *
Aluminum	0.00 **
Bronze	0.02 ***
Silver	0.00 ****
Steel M-50	0.00 *****
Mild Steel	0.00 ******
Titanium	0.00 *******

*	Multicolor discoloration
**	Faint bluish discoloration
***	Multicolor discoloration
****	Dark tarnish
*****	Bronze & purple discoloration
******	Bronze & purple discoloration
*******	Light tarnish

▽ *Federal Test Method Standard 791b*
Method 5307.

TABLE CXXXIII CONTINUED

SAMPLE NUMBER ATL-3177 [7]

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	12.88
Viscosity @ 210 deg. F., cs.	3.44
Neutralization No., mg.KOH/g.	0.22

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	13.01
Viscosity @ 210 deg. F., cs.	3.44
Neutralization No., mg.KOH/g.	1.01
Evaporation Loss, %	0.7
Appearance after oxidation:	Dark brown, no precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity @ 100 deg. F., %	1.0
Increase in Viscosity @ 210 deg. F., %	0.0
Increase in Neutralization No., mg.KOH/g.	0.79

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00 *
Aluminum	0.00 **
Bronze	0.00 *
Silver	-0.04 ***
Steel M-50	0.00 ****
Mild Steel	0.00 ****
Titanium	0.00 **

* Multicolor discoloration
** Light tarnish
*** Dark tarnish
**** Bronze and purple discoloration

▽ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXIV

SAMPLE NUMBER ATL-3178

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 1

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	Change in Viscosity, % @ 210 deg. F.
Original	0.24	-----	14.08	3.66	-----	-----
16 hrs.	0.47	+0.23	14.15	3.68	+0.5	+0.5
24 hrs.	0.57	+0.33	14.20	3.70	+0.8	+1.1
40 hrs.	0.78	+0.54	14.29	3.73	+1.5	+1.9
48 hrs.	0.92	+0.68	14.79	3.71	+5.0	+1.4
64 hrs.	1.06	+0.82	14.16	3.71	+0.6	+1.4
72 hrs.	1.22	+0.98	14.22	3.71	+1.0	+1.4
88 hrs.	1.43	+1.19	14.29	3.71	+1.5	+1.4
96 hrs.	1.45	+1.21	14.40	3.73	+2.3	+1.9

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	-0.09	Purple and light blue discoloration
Silver	-0.02	Light tarnish
Steel M-50	0.00	Brassy discoloration
Mild Steel	0.00	Brassy discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	2.3
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge of centrifuge	None

TABLE CXXXIV CONTINUED

SAMPLE NUMBER ATL-3178

CORROSION - OXIDATION
FTM Std. 791b
Method 5307
Run 2

	Neutralization No., mg.KOH/g.	Neutralization No., Change, mg.KOH/g.	Viscosity @ 100 deg. F., cs.	Viscosity @ 210 deg. F., cs.	Change in Viscosity, % @ 100 deg. F.	@ 210 deg. F.
Original	0.24	-----	14.08	3.66	-----	-----
16 hours	0.40	+0.16	14.12	3.67	+0.3	+0.3
24 hours	0.50	+0.26	14.17	3.68	+0.6	+0.5
40 hours	0.73	+0.49	14.36	3.68	+2.0	+0.5
48 hours	0.80	+0.56	14.24	3.72	+1.1	+1.6
64 hours	1.02	+0.78	14.29	3.73	+1.5	+1.9
72 hours	1.12	+0.88	14.36	3.69	+2.0	+0.8
88 hours	1.29	+1.05	14.41	3.70	+2.3	+1.1
96 hours	1.37	+1.13	14.38	3.70	+2.1	+1.1

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00	
Aluminum	0.00	
Bronze	-0.07	Purple and multicolor discoloration
Silver	-0.02	Light tarnish
Steel M-50	0.00	Brassy discoloration
Mild Steel	0.00	Brassy discoloration
Titanium	0.00	Light tarnish

Evaporation Loss, %	3.2
Appearance of tube	A few small gelatinous globules
Appearance of oil	Dark brown, no precipitate
Sludge by centrifuge	None

TABLE CXXXIV CONTINUED

SAMPLE NUMBER ATL-3178 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 1

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	14.08
Viscosity @ 210 deg. F., cs.	3.66
Neutralization No., mg. KOH/g.	0.24

Tests onthe Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.33
Viscosity @ 210 deg. F., cs.	3.69
Neutralization No., mg. KOH/g.	1.81
Evaporation Loss, %	0.3
Appearance after oxidation:	Dark Brown, No precipitate
Appearance of tube	A few small gelatinous globules
Increase in Viscosity, % (@ 100 deg. F.)	1.8
Increase in Viscosity, % (@ 210 deg. F.)	0.8
Increase in Neutralization No., mg. KOH/g.	1.57

Loss of Weight of Metals, mg./sq. cm.:

Magnesium	0.00
Aluminum	0.00
Bronze	0.05 *
Silver	0.00 **
Steel M-50	0.00 ***
Mild Steel	0.00 ****
Titanium	0.00 *****

* Dark brown discoloration
** Light tarnish
*** Dark bronze discoloration
**** Dark bronze discoloration
***** Light tarnish

∇ Federal Test Method Standard 791b
Method 5307.

TABLE CXXXIV CONTINUED

SAMPLE NUMBER ATL-3178 ∇

CORROSION AND OXIDATION STABILITY TEST
96 hours at 347 deg. F.
Without Intermediate Samples
Run 2

Tests on the Original Oil:

Viscosity @ 100 deg. F., cs.	14.08
Viscosity @ 210 deg. F., cs.	3.66
Neutralization No., mg.KOH/g.	0.24

Tests on the Oxidized Oil:

Viscosity @ 100 deg. F., cs.	14.45
Viscosity @ 210 deg. F., cs.	3.69
Neutralization No., mg.KOH/g.	1.54
Evaporation Loss, %	0.7
Appearance after oxidation:	Dark brown, no precipitate
Increase in Viscosity @ 100 deg. F., %	2.6
Increase in Viscosity @ 210 deg. F., %	0.8
Increase in Neutralization No., mg.KOH/g.	1.30
Appearance of tube	A few small gelatinous globules

Loss of Weight of Metals, mg./sq.cm:

Magnesium	0.00
Aluminum	0.00
Bronze	-0.04 *
Silver	0.00 **
Steel M-50	0.00 ***
Mild Steel	0.00 ***
Titanium	0.00 **

* Dark brown and slightly olive green discoloration
** Light tarnish
*** Dark bronze discoloration

∇ Federal Test Method Standard 791b
Method 5307.

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